British Geological Survey

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Mineral Resource Information for Development Plans

South Wales: Resources and Constraints

BRITISH GEOLOGICAL SURVEY

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Mineral Resources Series

Mineral Resource Information for Development Plans Phase One South Wales: Resources and Constraints

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This report accompanies the 1:100 000 scale maps:
South Wales Mineral Resources (other than Coal)
South Wales Coal Resources

Cover photograph
Craig-yr-Hesg Quarry, Pontypridd;
ARC - South Wales. Pennant sandstone, (Grovesend Beds) High Specification Aggregate

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SUMMARY

This report is one of a series prepared by the British Geological Survey for various administrative areas in England and Wales for Phase One of the Department of the Environment, Transport and the Regions Research Project 'Mineral Resource Information for Development Plans.'

The report and accompanying maps relate to the area of fifteen Mineral Planning Authorities in South Wales: Blaenau Gwent, Brecon Beacons National Park, Bridgend, Caerphilly, Cardiff, Carmarthenshire, Merthyr Tydfil, Monmouthshire, Neath Port Talbot, Newport, Rhondda Cynon Taff, Swansea, Torfaen, Vale of Glamorgan, and parts of Powys. The report and maps delineate and describe the mineral resources of current, or potential, economic interest in the area and relate these to national planning designations which may represent constraints on the extraction of minerals. Three major elements of information are presented and described:

- the geological distribution and importance of mineral resources
- the extent of mineral planning permissions and the location of current mineral workings
- the extent of selected planning constraints (national statutory designations)

This wide range of information, much of which is scattered and not always available in a consistent and convenient form, is presented on two digitally-generated summary maps, Mineral Resources (other than coal) and Coal Resources. The maps are produced at 1:100 000 scale, which is convenient for overall display and allows for a legible topographic base on which to depict the information. In addition, as the data are held digitally using a Geographical Information System (GIS), easy revision, updating and customisation are possible, including presentation of subsets of the data at larger scales.

Basic mineral resource information is essential to support mineral exploration and development activities for resource evaluation and planning, as baseline data for environmental impact studies and environmental guidelines and, in addition, to enable a sustainable pattern and standard of development to be achieved by valuing mineral resources as national assets.

The purpose of the work is to assist all interested parties involved in the preparation and review of development plans, both in relation to the extraction of minerals and the protection of mineral resources from sterilisation, by providing a knowledge base on the nature and extent of mineral resources and the environmental constraints which may affect their extraction. However, it is anticipated that the maps and report will also provide valuable data for a much wider audience, including the minerals industry, the Coal Authority, the Planning Inspectorate, the Environment Agency, the Countryside Council for Wales, other agencies and government bodies, environmental interests and the general public.

The mineral resource information has been produced by the collation and interpretation of data principally held by the British Geological Survey. The methodology for the collection and display of the data is described and a range of sources of information and further contacts is presented. The mineral resources covered are limestone, sandstone, coal, oil and gas, clay and shale, fireclay, igneous rock, slate, sand and gravel, silica rock, metalliferous minerals and secondary aggregates.

INTRODUCTION

'........ it will become increasingly important to have reliable information about the nature, quantity and location of mineral resources, as workable reserves in environmentally acceptable areas become scarcer.'

Sustainable Development: The UK Strategy.
Government's response to the Rio Earth Summit.

This report is one of a series prepared by the British Geological Survey for various administrative areas in England and Wales as part of the Department of the Environment, Transport and the Regions Research Project 'Mineral Resource Information for Development Plans.'

The report and associated maps relate to the area of fourteen new Unitary Authorities in South Wales, which were created in April 1996, and which are now Mineral Planning Authorities (MPAs). They are Blaenau Gwent, Brecon Beacons National Park, Bridgend, Caerphilly, Cardiff, Carmarthenshire, Merthyr Tydfil, Monmouthshire, Neath Port Talbot, Newport, Rhondda Cynon Taff, Swansea, Torfaen, Vale of Glamorgan, and, additionally, parts of Powys (Figure 1). This area does not coincide with that of the South Wales Regional Working Party on Aggregates which additionally includes the whole of Ceredigion, Powys, Pembrokeshire and the Pembrokeshire Coast National Park.

The report and maps delineate and describe the mineral resources of current, or potential, economic interest in the area and relate these to national planning designations which may represent constraints on the extraction of minerals. The purpose of the work is to assist all interested parties involved in the preparation and review of development plans, both in relation to the extraction of minerals and the protection of mineral resources from sterilisation, by providing a knowledge base, in a consistent format, on the nature and extent of mineral resources and the environmental constraints which may affect their extraction. An important objective is to provide baseline data for the long term. The results may also provide a starting point for discussions on specific planning proposals for minerals extraction or on proposals which might sterilise resources.

The report and maps generally represent the situation at 1st January 1997. All the data are held in digital form which can be readily updated and revised on a regular basis and also provides scope for producing customised maps of selected information, including the display of part of an administrative area on a larger scale or a grouping of administrative areas to provide a broader picture. The Mineral Resource Maps are presented at 1:100 000, which is a convenient scale for overall display and to show the information on a legible topographic base.

Our industrialised society is highly dependent on minerals, and their extraction and use makes a major contribution to wealth creation, the nation's infrastructure and the quality of life of individuals. Mineral resources are national assets. However, minerals can only be worked where they occur and their extraction, particularly in the densely populated landmass of Britain, may cause conflicts with other desirable aims of society, either by loss or change to valued landscapes, habitats or artefacts or due to amenity impact.

Basic mineral resource information is essential to support mineral exploration and development activities. In the wider context of sustainable development, mineral resource data are also required for resource evaluation and planning, and for the establishment of baseline data needed for environmental impact studies and environmental guidelines. Moreover, knowledge of the extent and quality of mineral resources, and their rate of extraction, can help to value them as national assets, to ensure that the capital they represent is managed properly and rates of depletion monitored. This will ensure that a sustainable pattern and standard of development is achieved.

Minerals Planning

It is the function of the planning system through the development plan and individual decisions to achieve a balance between competing objectives. Achieving that balance requires adequate data on the relevant competing objectives, including the extent and details of mineral resources. As workable resources in environmentally acceptable areas are becoming scarcer, it will be become increasingly important in the policy development process to have comparative and reliable data on the distribution and quality of such resources.

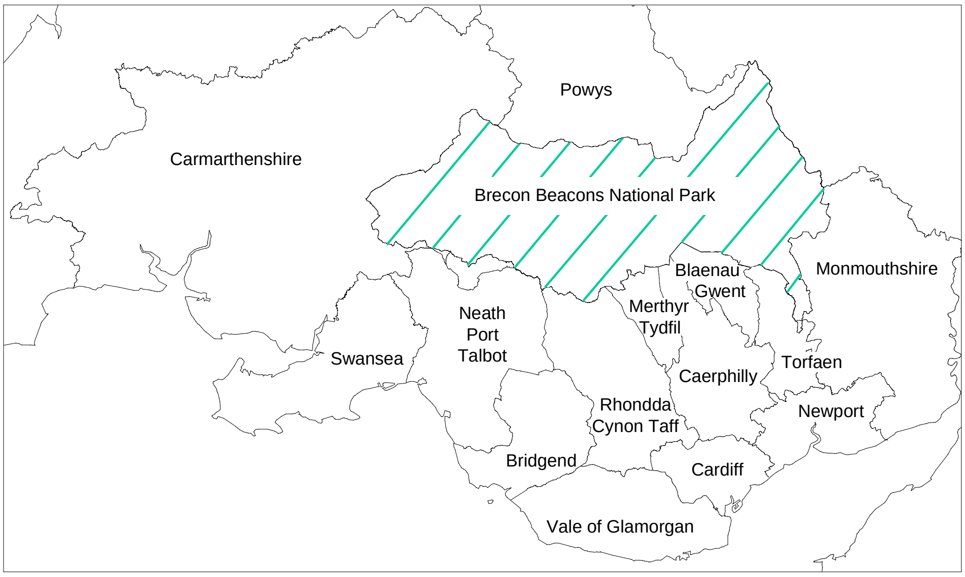


Figure 1 Map showing the Mineral Planning Authority areas covered by the report

The 'development plan' includes structure plans, which contain strategic planning policies, and local plans, containing detailed policies and proposals, or unitary development plans, which combine both functions. Relevant authorities must produce either a Minerals Local Plan or mineral policies within a unitary development plan. Development plans set out the main considerations on which planning applications are determined and form the essential framework of the planning system. The importance of the development plan system in planning decisions is emphasised by Section 54A of the Town and Country Planning Act 1990, which requires that planning applications and appeals be determined in accordance with the development plan unless material considerations indicate otherwise. The planning system is, therefore, a plan-led system. Development plans are produced through an extensive process of consultation with prospective developers and the general public. Development plan preparation must take account of Government guidance. This is primarily set out in Planning Guidance: Planning Policy (Wales) and its associated Technical Advice Notes, which provides advice on a range of general and specific issues, and in Minerals Planning Guidance, which provides more detailed advice on minerals-related issues. The Welsh Office is currently reviewing all minerals planning guidance in Wales and consultation on the draft guidance will take place in due course.

The Planning and Compensation Act 1991 introduced a mandatory requirement that all Mineral Planning Authorities (MPAs) in England and Wales prepare a local plan or unitary development plan, which set out the policies and proposals against which mineral planning applications and appeals are determined. Such plans are intended to provide a clear guide to mineral operators and the public where mineral extraction is likely in principle to be acceptable and where not. They cover a period of at least 10 years and are reviewed every five years to take account of new information and changing circumstances. Unitary development plans have similar requirements. MPAs are, therefore, required to undertake regular assessments of the existing resources in their areas and of the reserves for which planning permissions have been granted.

The key elements of a minerals local plan or of the minerals policies of a unitary development plan are:

- to balance, through its policies, the essential need for minerals against protection of the environment and local amenity
- to make an appropriate provision for the supply of mineral and provide an effective framework within which the minerals industry may make planning applications
- to identify areas of possible future mineral working

- to prevent unnecessary sterilisation of resources by the use of safeguarding policies

It follows that information on the extent, quality and, if possible, quantity of mineral resources is an essential prerequisite for the production of mineral local plans or unitary development plans, both in the context of identifying areas of future mineral working and the longer term objective of the protection of important mineral resources against sterilisation. Such data should be available to all parties to assist them in their contribution to the development plan process, both to protect mineral resources from sterilisation and to provide for sufficient resources to meet the needs of society. This work is intended to assist that process.

Three major elements of information are presented and described:

- the geological distribution and importance of mineral resources
- the extent of mineral planning permissions and the location of current mineral workings
- the extent of selected planning constraints (national statutory designations)

An additional and important objective is that the data should be capable of easy revision and update. The maps thus bring together a wide range of information, much of which is scattered and not always available in a consistent and convenient form. It is anticipated that the maps and report will also provide valuable background data for a much wider audience, including the different sectors of the minerals industry, other agencies and authorities (e.g. the South Wales Regional Working Party on Aggregates, the Planning Inspectorate, the Coal Authority, the Environment Agency, the Countryside Council for Wales), environmental interests and the general public.

The mineral resource information has been produced by the collation and interpretation of data principally held by the British Geological Survey. Resource areas are taken, with some generalisations and modifications, from available BGS 1:50 000 or 1:63 630 scale maps (Figure 9). These are based on 1:10 560 or 1:10 000 scale surveys ranging in age from 1902 to 1983; the more recent contain the most up-to-date interpretation. Modern geological maps are not available for the northern part of the region, and use has, therefore, been made of the BGS 1:250 000 UTM Series. Sources are given in the selected bibliography and appendices.

Mineral resource classification

Mineral resources are natural accumulations of minerals, or bodies of rock, that are, or may become, of potential economic interest as a basis for the extraction of a commodity. However, the identification and delineation of mineral resources is inevitably somewhat imprecise as it is limited not only by the quantity and quality of data currently available, but also involves predicting what might, or might not, become economic to work in the future. Mineral resources are economic as well as physical entities. The assessment of mineral resources is thus a dynamic process which must take account not only of geological reinterpretation, but also of the continually evolving demand for minerals, or specific qualities of minerals, due to changing economic, technical and environmental factors. Areas that may be of potential economic interest as sources of minerals may thus change with time.

The two maps of South Wales show the extent of **inferred mineral resources**, that is those mineral resources that can be defined from available geological information. They have neither been evaluated by drilling or other sampling methods, nor had their technical properties characterised, on any systematic basis. Mineral resources defined on the map delineate areas within which potentially workable minerals may occur. These areas are not of uniform potential and also take no account of the planning constraints that may limit mineral working.

That part of a **mineral resource** which has been fully evaluated and is commercially viable to work is called a **reserve** or **mineral reserve**. The relationship between **measured, indicated** and **inferred resources** and evaluated commercial deposits (**reserves**) is described in more detail in Appendix 3. In the context of land-use planning, however, the term **mineral reserve** should strictly be further limited to those minerals for which a valid planning permission for extraction currently exists (i.e. **permitted reserves**). Without a legal planning consent no mineral working can take place and consequently the inherent economic value of the mineral resource cannot be released and resulting wealth created.

Mineral workings and planning permissions

The location and name of mineral workings that are currently active or temporarily inactive, together with the main mineral commodities they produce, are shown on the map and listed in Appendix 1.

The extent of all known mineral planning permissions (other than coal) is shown on the Mineral Resources Map. These include all mineral permissions granted since 1st July 1948 and IDO permissions, whatever their subsequent status in relation to legislation relating to the Planning and Compensation Act 1991 and the Environment Act 1995. Planning permissions cover active mineral workings, former mineral workings and, occasionally, unworked deposits. They represent areas where a commercial decision to work minerals has been taken in the past and where the resource may have been depleted to a greater or lesser extent. Certain mineral extraction sites where it is known that a planning permission existed but where the information is unavailable have been indicated as ‘planning permission undefined’.

The mineral planning permissions were made available by the various unitary authorities in South Wales who are also the new mineral planning authorities. No claim is made for the accuracy and completeness of the information presented. With respect to coal a somewhat different approach has been adopted. Areas of former opencast coal sites are shown based largely on information made available by the Coal Authority. For active coal sites the extent of the licence area for coal extraction is also shown and a distinction is made between underground and opencast licences. This information rapidly becomes out of date and is thus only correct to the date shown on the map. More detailed information on specific sites may be obtained from the Coal Authority (Appendix 2).

The present physical and legal status of individual permissions is not qualified on the maps or in the report. The areas shown may, therefore, include inactive sites, where the permission has expired due to the terms of the permission, i.e. a time limit, and inactive sites where the permission still exists. Sites which have been restored have not been separately identified. A mineral planning permission may extend beyond the mapped resource as it may make provision for operational land, including plant and overburden tips, or it may extend to an easily identified or ownership boundary. Information on the precise status and extent of individual planning permissions should be sought from the appropriate Mineral Planning Authority (Appendix 2).

Environmental designations

The map shows the extent of selected, nationally-designated planning constraints as defined for the purposes of this study. These constraints are defined on a common national basis and therefore represent a consistent degree of constraint across the country. No interpretation should be made from the maps with regard to the relative importance of the constraints, either in relation to mineral development proposals or in relation to each other (Figure 2). Users should consult policy guidelines issued by the relevant Government department, statutory agency or mineral planning authority.

The constraints shown on the map are:

- National Parks
- Area of Outstanding Natural Beauty (AONB)
- Heritage Coast
- National Nature Reserve (NNR)
- Site of Special Scientific Interest (SSSI)
- Scheduled Monument

Mineral development may also be constrained by many other factors not shown on the maps, including local landscape designations, considerations relating to the protection of other resources, such as groundwater and agricultural land quality, and local amenity or environmental concerns such as noise, traffic and visual impact. These have been excluded because the constraint may not always be applicable. The extent or degree of relevance of such constraints can be ascertained from the relevant statutory agency or Mineral Planning Authority (Appendix 2).

Figure 2 Brynhenllys Opencast Coal Site, near Gurnos, Powys, partly in the Brecon Beacons National Park

An example of one such constraint is groundwater issues. In this context the BGS in conjunction with the Soil Survey and Land Research Centre have been commissioned by the Environment Agency to produce groundwater vulnerability maps for England and Wales on the scale of 1:100 000. Most of South Wales is covered by groundwater vulnerability maps. They identify areas in which groundwater resources require protection from potentially polluting activities. The maps are designed to be used by planners, developers, consultants and regulatory bodies to ensure that developments conform to the NRA's (now Environment Agency) Policy and Practice for the Protection of Groundwater.

The Countryside Council for Wales provided digital data on SSSIs, NNRs and AONBs. Information on the location of Scheduled Monuments has been obtained in digital form from CADW Welsh Historic Monuments. These are plotted using a centred NGR symbol and consequently the actual area and/or length of a monument protected by the legal constraints of scheduling cannot be represented on the map. The areas shown as NNRs and SSSIs may also be subject to proposed international designations reflecting their wider ecological importance. They may include Ramsar sites (wetlands of international importance as listed in accordance with the Ramsar convention), or Special Protection Areas (SPAs) and Special Areas of Conservation (SACs) as identified in accordance with EC Directives on the conservation of wild birds and natural habitats, respectively.

MINERAL RESOURCES

The mineral resources of this area of Wales have been of considerable importance in the industrial development of Britain and in the associated growth in both the population and the economy of the area. The nature and distribution of these resources is directly related to the comparatively complex geological history of the area over several hundred million years which has produced a wide range of rock types. These comprise a variety of mainly sedimentary rocks ranging in age from Precambrian to Jurassic. Igneous rocks, both extrusive and intrusive, are sparsely distributed and only occur in the older rocks. Superficial (Drift) deposits occur over parts of the area and offshore. Figure 3 summarises the relationship between mineral resources and uses and products.

The rock types occurring in South Wales differ greatly in their economic potential. This potential principally reflects their physical and chemical properties, their extent and thickness and also their accessibility to markets. Rock properties, such as composition and strength, depend on the geological conditions under which the rocks were formed, and on their subsequent burial, tectonic and weathering history. For example, the tectonic compression associated with Variscan mountain building episode, about 280 million years ago, greatly improved the strength and abrasion resistance of Pennant sandstones producing rocks with exceptional skid resistance properties. The same event also contributed to the formation of Britain's only significant anthracite resource and also resulted in widespread faulting within the South Wales Coalfield, which has created problems for modern, mechanised deep mining.

The Mineral Resource Maps of South Wales which accompany this report highlight the relative importance of the different rock types as potential sources of minerals. Those of Lower Palaeozoic age (mainly Ordovician and Silurian) occur extensively in the north-west of the area and whilst they have hosted metal-mining activities, including those for gold, in the past they are of comparatively little economic importance today. Although dominated by mudstones, sandstones do occur and are locally utilised for roadstone.

The late Silurian to early Devonian Lower Old Red Sandstone flanks the South Wales Coalfield to the north, notably in the Brecon Beacons and Black Mountains, and to the east towards Monmouth and Chepstow. The lower half of the succession is mainly red mudstone, while the upper half is typified by thick locally pebbly sandstones with very subordinate mudstones. Units of conglomerate are developed around Cardiff. The Upper Old Red Sandstone (Upper Devonian) has a similar outcrop and also consists mainly of sandstone. The Old Red Sandstone has been of limited economic potential and only locally worked as a source of building stone and for sand and gravel (conglomerate).

In contrast Carboniferous strata, comprising the Carboniferous Limestone, the Millstone Grit Group and particularly the Coal Measures, formed the basis of the industrial development of South Wales and these rocks still comprise the principal mineral resources in the area. It was the juxtaposition of coal, iron ore (mainly blackband ironstones), limestone, fireclay and silica rock which provided the basis for the Industrial Revolution in the latter part of the 18th century and led to the rapid expansion of mineral production in the region. However, during the 20th century iron ore production has ceased. There has also been a dramatic decline in the deep mine production of coal, which has only been partially replaced by an increase in opencast production, which started during the Second World War. Changes in iron and steelmaking technology have also resulted in the demise in the use of fireclay and silica refractories, and the use of limestone and dolomite as a metallurgical flux is now overshadowed by their use in construction. In addition, the former use of Pennant sandstone as a building stone has been replaced by its current use as a premium road surfacing aggregate.

The younger rocks in South Wales are of Triassic and Jurassic age. These are restricted to the Vale of Glamorgan and around Newport. The Jurassic rocks mainly consist of interbedded mudstones and limestones and these are utilised for cement manufacture. Superficial deposits of Quaternary age mantle much of the South Wales landscape, especially the valleys. They mainly comprise the deposits of the last glaciation and are dominated by till (boulder clay) and glaciofluvial sand and gravel. Postglacial deposits which accumulated in the last 15 000 years include the alluvium (silts, sands and gravels) of the modern rivers, wind blown sands adjacent to the coast, hill peat, beach deposits and the marine sand banks of the Bristol Channel. In contrast to superficial deposits elsewhere in Britain, where they are an important source of sand and gravel, onshore deposits in South Wales have been little worked and marine-dredged sands from the Bristol Channel are a major source of supply.

Currently the most important mineral resources in South Wales are coal and those used for aggregate purposes. The demand for these materials will be the most significant factor in mineral development in the foreseeable future. Issues relating to the level of demand, production and constraints on these materials will be the most important matters that will need to be resolved through the mineral planning process.

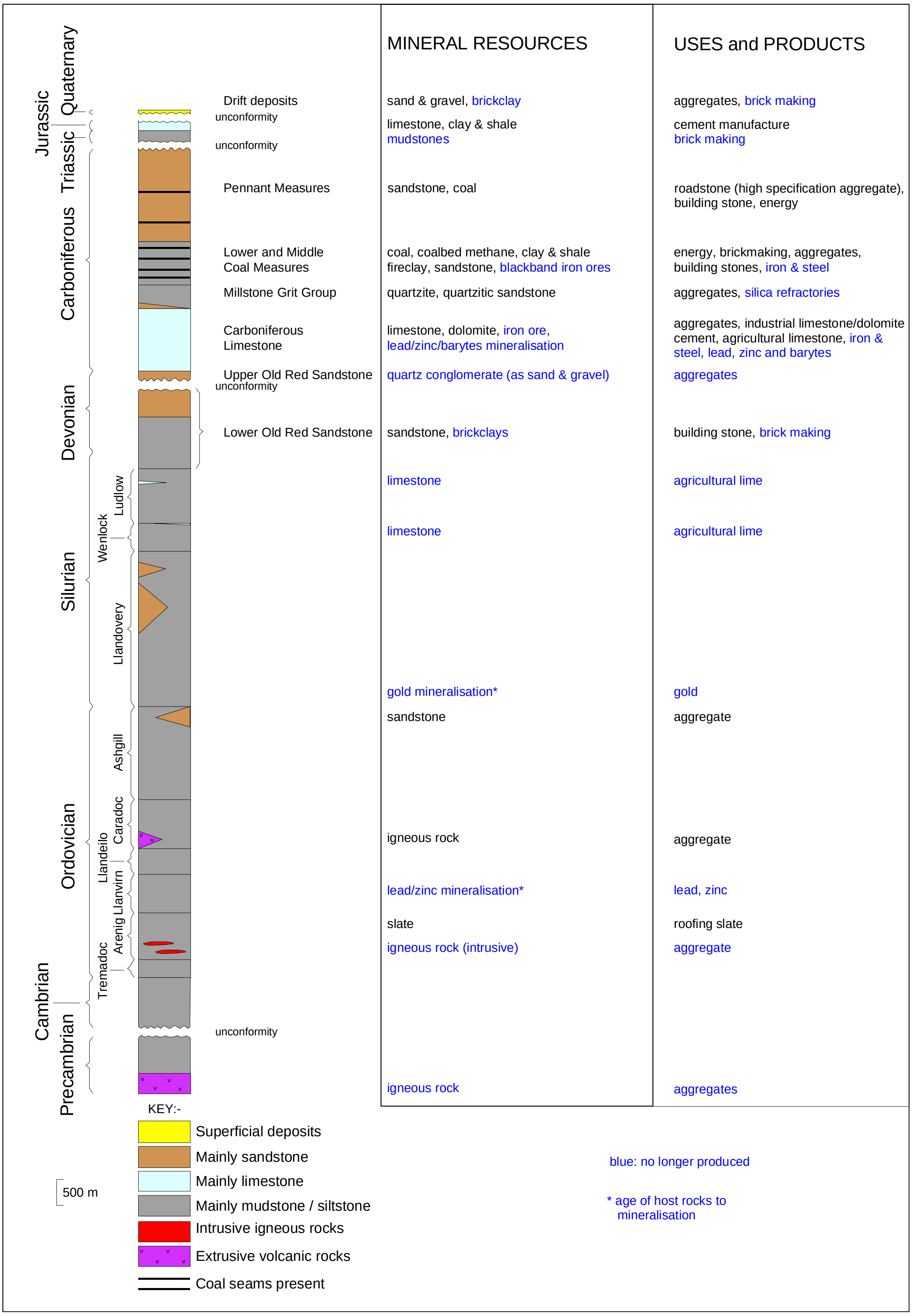


Figure 3 Generalised vertical section for the rocks of South Wales and their uses

LIMESTONE

South Wales is one of the major centres of limestone (including dolomite) production in Britain. In the past the limestone and dolomite resources of the area were extensively quarried for use as a flux in the local iron and steel industry. Most is now consumed in the construction industry and of a total output of 11.62 million tonnes in 1993, 10.15 million tonnes was sold for aggregate use and 1.47 for non-aggregate applications (South Wales Regional Working Party on Aggregates, 1994). Cement manufacture and agriculture are the principal non-aggregate applications and only minor quantities of both limestone and dolomite are produced for industrial applications, principally as a flux in ironmaking. Small amounts are also produced for building stone.

The limestone resources of South Wales are divided into two broad categories and these are shown on the map:

> **Carboniferous limestones** – these rocks crop out on the flanks of the South Wales Coalfield, and in the Chepstow area, and form thick, relatively consistent deposits of relatively hard limestone and dolomite, ideally suited to the production of crushed rock aggregates. They are the most important source of coarse aggregate in the region and are worked at over 20 quarries, mainly concentrated around Bridgend and Cardiff.
>
> **Jurassic limestones** – these occur extensively in the Vale of Glamorgan and consist of a thick sequence of interbedded limestones and mudstones. They are generally unsuitable for aggregate use but are quarried near Barry for cement manufacture.

Silurian limestones crop out to the east of Pontypool within the Usk anticline, where they occur as thin limestones within mudstones. Although Silurian limestones are worked outside South Wales they have been excluded from the map because of their unsuitability for more demanding aggregate applications.

The limestone resources of South Wales have been described in some detail in various BGS reports (Harrison, 1983; 1984; 1991) and the general distribution of limestone resources in the area is, therefore, well understood. These reports form the basis for the following text.

Carboniferous limestones

The Carboniferous limestones of South Wales comprise a thick and relatively consistent succession of limestone and dolomite, ideally suited to the production of crushed rock aggregates. The limestones are varied both in lithology and thickness resulting in a complicated succession of formation names (see Figure 4). All the main formations with the exception of the Lower and Upper Limestone Shales and localised areas of coarse-grained dolomite yield good quality aggregates suitable for a wide range of construction applications with the exception of road surfacing aggregate in demanding traffic conditions. In some areas parts of the sequence are composed of high purity limestones (> 97 per cent $CaCO_3$) and these areas are defined on the map. In addition, parts of the sequence are dolomitised and the distribution of dolomite is also defined on the map. In places the limestones are overlain by substantial thicknesses of superficial deposits. These have been omitted from the map to assist clarity, but the information is held in digital form in the database.

The limestones are principally worked as a source of crushed rock aggregate, suitable for use as roadstone and concrete aggregate, but are also used in cement manufacture and for industrial and agricultural uses.

The limestone resources of South Wales can be conveniently considered in three areas; the **Northern outcrops** (Kidwelly–Ammanford–Merthyr Tydfil–Abergavenny–Pontypool), the S**outhern outcrops** (Pontypool–Cardiff–Bridgend–Gower), and the **Chepstow area**.

Southern outcrops
The Carboniferous limestones cropping out on the southern flank of the South Wales Coalfield comprise a thick sequence of northerly dipping, bedded grey and pale grey limestones and dolomites, with argillaceous (clayey) limestones. The limestones are divided into a number of formations (Table 1).

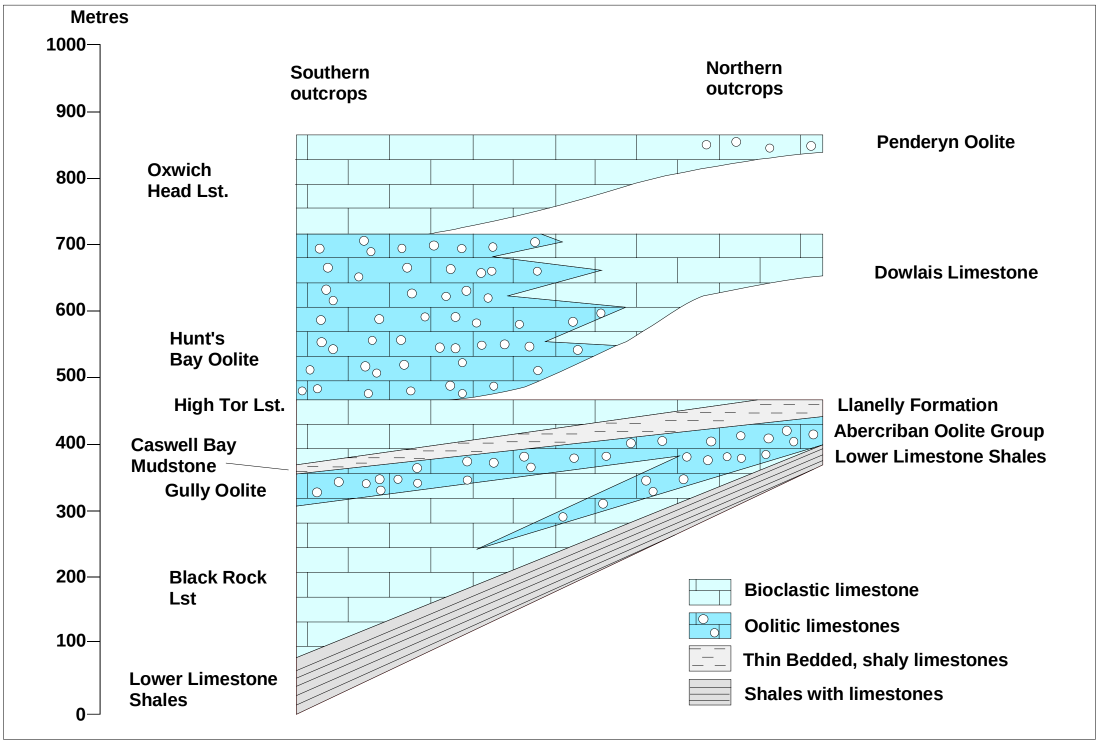


Figure 4 Schematic diagram to show variations in the Carboniferous Limestone succession of South Wales

The Upper and Lower Limestone Shales, which overlie and underlie the limestone succession, are dominated by mudstones with interbedded thin, muddy limestones. Although they have locally been worked for building stone they are unsuitable for use as aggregates and are, therefore, excluded from the map. Locally, around Bridgend and Cardiff, limestone beds within the Lower Limestone Shales are thicker and less argillaceous and are capable of producing strong aggregate materials. All other formations (with the exception of the thin, argillaceous Caswell Bay Mudstone) are capable of producing strong, low porosity aggregates. The thickest and most widespread formation is the Black Rock Limestone which comprises a sequence of dark grey, partially argillaceous and cherty limestones. These limestones are quarried at several sites for aggregate use.

Table 1 Simplified stratigraphy and thickness (m) of the Carboniferous Limestone (southern outcrops) in South Wales

Formation	Gower (m)	Bridgend (m)	Cardiff (m)	Taff's Well–Pontypool (m)
Upper Limestone Shales	60	25	–	–
Oxwich Head Limestone	150	120	–	
Hunts Bay Oolite	250	230	–	Main Limestone
High Tor Limestone	100	60–150	130	40 – 540
Caswell Bay Mudstone	0–15	0–15	–	
Gully Oolite	25–45	50	80	
Black Rock Limestone	230	100–200	300–500	
Lower Limestone Shales	90	75	120	35–110

Dolomite is present throughout much of the Black Rock Limestone but dolomitisation is particularly pervasive within its upper part. The overlying sequence is generally less variable and is consistently of higher chemical purity. Relatively pure, massive or thick-bedded oolitic limestones characterise the Gully Oolite and Hunts Bay Oolite. Together with the pale grey, bioclastic limestones of the Oxwich Head Limestone (which is lithologically and stratigraphically equivalent to the very high purity Bee Low Limestones in Derbyshire) these limestones form a thick sequence of high purity limestones generally containing > 97 per cent $CaCO_3$. Some industrial grade limestone is produced from the Hunts Bay Oolite near South Cornelly. The High Tor Limestone is lithologically and chemically variable and extraction is solely for aggregate use.

In the eastern outcrop (Taff's Well–Pontypool) almost the whole sequence above the Lower Limestone Shales is dolomitised and is known as the Main Limestone (Table 1). The dolomites are massive or thick-bedded and are mostly fine or medium-grained in texture. They are generally much finer and denser than dolomitised Carboniferous limestones elsewhere and hence produce a strong and durable aggregate (Table 4). They have an unusually high resistance to abrasion and are therefore suitable for railway track ballast, where such properties are critical. Other limestones/dolomites in Britain are unacceptable for this purpose. Locally, the Main Limestone contains some coarse-grained dolomites which are significantly weaker and less durable than is typical of the finer-grained varieties. The dolomite purity typically varies between very high purity and low purity. It usually contains between 17.5 per cent and 22 per cent MgO and this compares favourably with most commercial dolomites used as a refractory material or as a fluxing agent. However, the amount of impurities, such as silica, iron oxide and alumina, is a prime consideration in the selection of dolomite for industrial use. Small amounts of dolomite are sold for industrial applications.

Northern outcrop

Carboniferous limestones form a narrow outcrop around the northern flank of the South Wales Coalfield and dip southwards. They are quarried for aggregates at several sites between Kidwelly and Trefil, east of Merthyr Tydfil. The resource has been defined by the base of the limestones and the base of the overlying Millstone Grit, which may also be suitable as a source of aggregate. The limestone sequence is much thinner than in the southern outcrops and the limestones are significantly different in lithology, although broadly similar in aggregate properties. A different stratigraphical scheme is used to describe the succession (Figure 4), although it is possible to correlate certain formations.

Table 2 Simplified stratigraphy and thickness (m) of the Carboniferous Limestone (Northern outcrops) in South Wales

Kidwelly–Penwyllt	**thickness (m)**	**Merthyr Tydfil**	**thickness (m)**
Upper Limestone Shales	5–10	–	
Penwyllt Limestone	20–85	–	
Penderyn Oolite	0–30	–	
Greenhall Limestone	0–20	–	
Cil-yr-Ychen Limestone	60–125	Dowlais Limestone	30–65
–		Llanelly Formation	5–20
–		Abercriban Oolite Group	30–45
Lower Limestone Shales	10–25	Lower Limestone Shales	15–30

The Lower and Upper Limestone Shales are similar in lithology to those of southern outcrops, although considerably reduced in thickness. Limestones of Black Rock Limestone lithology are not developed in the north, but in the Merthyr–Abergavenny area they are replaced by a unit of pale grey, oolitic limestones, the Abercriban Oolite Group (Table 2). This formation is partially dolomitised and this increases in intensity south–eastwards into the dolomite belt. The overlying Llanelly Formation is a thin and varied unit containing limestones, mudstones and sandstones.

The Dowlais Limestone is the thickest limestone unit in eastern areas and is equivalent to the lithologically similar Cil-yr-Ychen Limestone further west. These limestones are the major quarried formations in the region. Both the Dowlais and Cil-yr-Ychen limestones consist of a monotonous series of well-bedded, dark grey bioclastic and oolitic limestones (they are the stratigraphical equivalent to the Hunts Bay Oolite further south) which produce strong aggregates. They are, however, variable in chemical purity due to varying silica and clay contents and are generally classified as medium or high-purity limestone resources. The most consistently pure limestones in the northern outcrops are the oolitic limestones of the Abercriban Oolite Group in the east, and the Penderyn Oolite in the west. In the past they were extensively quarried for use as a blast furnace flux, but today only small amounts are used for this purpose.

The Penwyllt Limestone is a relatively thick and consistent limestone unit, comprising well-bedded, dark grey bioclastic limestones and is quarried at several sites for aggregate use.

The limestone resources of the northern outcrops are of mixed quality, reflecting the relatively thin and variable nature of the limestone formations. The most important resources are the Penwyllt, Cil-yr-Ychen and Dowlais limestones.

Chepstow area

The Carboniferous Limestone of the Chepstow area is an important source of crushed rock aggregate, particularly the Lower Dolomite and Drybrook Limestone. The succession reaches a maximum thickness of around 500 m and contains significant developments of dolomite and sandstone (Table 3). The latter are also suitable for aggregate use. Parts of the sequence are of high chemical purity, although purity is variable and commercial extraction is solely for aggregate use. The chemistry of the Lower Dolomite is also variable, although typically the dolomites contain 17–20 per cent MgO and around 30–32 per cent CaO. Silica is the main variable and impurity.

Table 3 Geological succession and thickness (m) of the Carboniferous Limestone of the Chepstow area

	Thickness (m)
Upper Drybrook Sandstone	95
Drybrook Limestone	120
Lower Drybrook Sandstone	5–25
Whitehead Limestone	30–50
Crease Limestone	35
Lower Dolomite	90–120
Lower Limestone Shales	30–70

Table 4 Typical aggregate test data for Carboniferous limestones and dolomites in South Wales (from Harrison and others, 1983)

	PSV	AAV	AIV	ACV	Wet attrition value %
Northern Outcrops					
Penwyllt Limestone	–	9.1	22	–	–
Penderyn Oolite	–	8.8	27	–	–
Cil-yr-Ychen Limestone	38	7.7	24	19	–
Dowlais Limestone	43	9.4	21	21	–
Abercriban Oolite Group	–	8.7	25	–	–
Southern Outcrops					
Oxwich Head Limestone	–	11.0	22	23	–
Hunts Bay Limestone	44	10.1	23	23	9.4
High Tor Limestone	43	9.5	20	21	–
Gully Oolite	45	8.6	22	22	–
Black Rock Limestone	45	7.4	20	19	–
North-eastern Outcrops (Main Limestone)					
Fine grained dolomite	43	5.7	16	15	4.0
Coarse grained dolomite	–	16.0	31	27	10.6
Chepstow area					
Drybrook Limestone	45	7.2	21	19	–
Whitehead Limestone	–	6.2	25	25	–
Crease Limestone	–	9.4	23	–	–
Lower Dolomite	46	8.7	20	20	–

Definitions

Aggregate Abrasion Value (AAV)	Resistance of an aggregate to abrasion as measured in the aggregate abrasion test. The smaller the value the more resistance the rock is to abrasion. Abrasion resistance is particularly important for road surfacing materials.
Aggregate Crushing Value (ACV)	Resistance of an aggregate to crushing when subjected to a crushing force as measured by the aggregate crushing test. The smaller the value, the more resistant the rock is to crushing.
Aggregate Impact Value (AIV)	Resistance of an aggregate to repeated impact as measured by the aggregate impact test. The smaller the value, the more resistant the rock is to impact.
Polished Stone Value (PSV)	Resistance of an aggregate to polishing as measured in the accelerated polishing test. A measurement of skid resistance on road surfaces. The larger the value the more resistant the rock is to polishing.
Wet Attrition Value	A measurement of the suitability of an aggregate for use as railway ballast. The smaller the figure the more suitable the rock.

Jurassic limestones

The Carboniferous Limestone west of Cardiff is locally overlain by limestones of Jurassic age. These Lower Jurassic limestones cover an extensive area in the Vale of Glamorgan between Barry and Bridgend and consist of thin-bedded, dark grey, fine-grained limestones interbedded with mudstones. They have been divided into three formations (Table 5). A small area of Lower Jurassic rocks near Newport are not considered to be of economic significance and hence are not shown on the map.

Table 5 Stratigraphy and thickness of the Lower Lias of South Wales

	Thickness (m)	Lithology
Porthkerry Formation	>75	limestone and mudstones
Lavernock Shales	12	mainly mudstones
St Mary’s Well Bay Formation	16	limestones and mudstones

The limestone beds vary in thickness, but average around 0.5 m, and the mudstones are generally thinner. Limestone:mudstone ratios are mostly around 60:40, although the middle part of the Porthkerry Formation contains a higher proportion of limestone, with ratios of 80:20. Many of the limestone beds are partially silicified and chert nodules occur sporadically. A marginal facies of limestone breccias and conglomerates predominantly composed of fragments of Carboniferous Limestone, is developed around the Carboniferous Limestone outcrop.

The limestones are primarily of importance as a feedstock for the manufacture of cement at Aberthaw. The Porthkerry Formation is of cement grade throughout its outcrop, although the middle part of the formation is preferred due to its higher calcium carbonate content. Carboniferous limestones are used in conjunction with the Jurassic limestones to improve the lime content of the cement feed. The limestones are not generally quarried for aggregates (although individual beds of the limestones have physical and mechanical properties similar to those of the Carboniferous Limestone) due to their shaly character and also because of the proximity of the Carboniferous Limestone. However, the limestones have been used as a source of fill and building stone.

SANDSTONE

Sandstones are widespread in South Wales. Upper Carboniferous (Pennant) sandstones form the extensive high moorlands of the South Wales Coalfield and sandstone units within the Upper Carboniferous (Millstone Grit) and Devonian (Old Red Sandstone) form many of the prominent ridges bordering the Coalfield, particularly to the north. Older, Lower Palaeozoic (late Ordovician/Silurian) sandstones are also locally developed in a predominantly mudstone succession in the area to the north-west of the Afon Tywi.

Variation in the properties of sandstones is a function of differences in mineralogical composition (itself a function of source rock and depositional environment), grain size, burial history and tectonic setting. Sandstones were traditionally valued as building stone, but are now important sources of aggregates. Some sandstones are particularly valued as sources of high quality, skid-resistant aggregates used for road surfacing (so-called high specification aggregates), which are the premium products of the crushed rock quarrying industry. The sandstone resources of South Wales have been reviewed in two relatively recent reports prepared for the Department of the Environment by Travers Morgan Ltd (Thompson et al, 1993) and by BGS (Cox and others, 1986). A further BGS report (Adlam and others, 1984) describes the sandstone resources of the Caerphilly area but also included information on the Pontypridd and Swansea areas. These reports, and BGS maps and memoirs, form the basis of the following text on sandstone resources.

Carboniferous sandstones

Sandstones of Carboniferous age occur extensively in South Wales in two main groups:

Pennant sandstone. These rocks are the principal sandstone resource and comprises the largest outcrop of sandstones in South Wales, forming the upland plateau of the Coalfield. They occur within a sequence of thickly bedded sandstones, interbedded with mudstones and a few coals. The sandstones are hard 'impure' sandstones (greywackes) with a high strength and are extremely uniform in their lithology and aggregate properties. They provide some of the highest-quality skid resistant aggregates in Britain, typically with PSVs (Polished Stone Values) in excess of 68. They are quarried at five main sites throughout the Coalfield with a combined annual output of some 1.5 million tonnes. Small amounts are produced for building stone.

Millstone Grit and Lower/Middle Coal Measures sandstones. These are mainly quartzitic sandstones or conglomerates. They often form thin, laterally impersistent beds but thicker sandstone units are developed locally, particularly on the northern flank of the Coalfield. The outcrop is marked by numerous disused quarries but the sandstones are not currently worked to any extent due primarily to the proximity of better quality Pennant sandstone and Carboniferous Limestone aggregate resources.

Pennant sandstone

The Upper Coal Measures (Pennant Measures) of South Wales form a very thick sequence (over 1500 m in the west around Swansea) composed of dominant sandstones, separated by thinner mudstones and some coals (Figure 5). The sandstones are traditionally referred to as 'Pennant sandstone', and the Pennant Measures are subdivided on the basis of widely recognised coal seams into two major groups and six subgroups, which are shown in Figure 5.

The sandstones within these units are, however, remarkably consistent in both their lithology and aggregate properties. They are typically poorly-sorted, fine to coarse-grained, feldspathic and micaceous lithic greywackes (impure sandstones containing mineral and rock fragments set in a clay cement) which are bluish-grey when fresh but rapidly become rusty brown on weathering. The depth of subaerial weathering is highly variable and commonly ranges between 2 m and 10 m. Weathering is influenced by the distribution of joints, which are essentially vertical and are typically at spacings of about 1 m. The sandstones are mostly massively bedded but cross-bedding is a common feature and flaggy beds occur in weathered outcrops. Individual sandstone units are commonly up to 60 m thick and locally in excess of 150 m. The proportion of sandstone to mudstone within the Pennant Measures varies both vertically and laterally.

The Lower Pennant Measures are thickest (around 700 m) in the Swansea area but thin eastwards and northwards to a minimum of around 160 m at Pontypool. The Lynfi Beds are mostly dominated by mudstones; thick sandstones (up to 55 m thick) are developed only in the west of the region. The overlying Rhondda Beds are of more uniform character with some 75 per cent of the sequence comprising sandstones. Individual sandstone units locally exceed 150 m in thickness. The Brithdir Beds consist largely of sandstones with some units being over 120 m in thickness.

The Upper Pennant Measures are also thickest (about 950 m) in the Swansea area. The lower unit, the Hughes Beds, is predominantly composed of sandstone in the east of the area, but in the western part of the Coalfield thick sandstones are only present in the lower part. The Swansea Beds are only present in the western half of the Coalfield where they comprise a mixed sequence of sandstones and mudstones. The Grovesend Beds have only a small outcrop area and are also a mixed sequence of mudstones and sandstones.

Despite the considerable thickness and widespread distribution of the Pennant Measures, the aggregate properties of the sandstones are remarkably uniform (Tables 6 and 7).

Pennant sandstone aggregates are typically highly resistant to polishing (very high PSVs) and in most cases they combine durability (low AAVs) with adequate strength (relatively low AIVs and relatively high Ten Per Cent Fines values). They are, therefore, ideal materials for the demanding specifications required for road surfacing aggregates. Their high resistance to polishing is due to the range in hardness of their constituents minerals (quartz, rock fragments and clay cement), which results in a high degree of surface roughness. Compression of the Pennant sandstone during the Variscan mountain building episode substantially improved their strength and abrasion resistance and is the reason why their stratigraphical equivalents elsewhere in Britain are not of comparable quality.

Table 6 Typical aggregate test data from the Pennant sandstone (from Adlam and others, 1984)

	PSV	AAV	AIV	ACV
Grovesend Beds	72	9	24	19
Swansea Beds	72	10	25	19
Hughes Beds	71	8	22	18
Brithdir Bed	71	8	22	19
Rhondda Beds	67	9	20	17
Lynfi Beds	71	8	25	22

Table 7 Typical aggregate test data from the Pennant sandstone (based on Thompson and others, 1993)

	PSV	AAV	AIV	10% Fines (kN)	Water Absorption (%)
Grovesend Beds	71	9.9	21	203	0.9
Swansea Beds	72	10.2	26	-	0.8
Hughes Beds	70	9.2	24	228	1.4
Brithdir Bed	70	8.7	24	238	1.2
Rhondda Beds	68	8.7	27	183	1.03
Lynfi Beds	68	7.6	30	-	0.9

The major cause of variation in aggregate properties is the degree of weathering. Weathering weakens the aggregate and reduces its durability. All surface exposures of Pennant sandstone are weathered to some degree and the depth of weathering is controlled by the distribution of joints and other rock discontinuities. The data presented in Table 7 probably includes information from partially weathered samples. Aggregates derived from Pennant sandstone would be expected to have AAVs of 7–8 and AIVs of 20–21. Several studies (Adlam et al, 1984; Cox, 1986) have noted minor geographical variations in the aggregate quality of the Pennant sandstone. There is a general tendency for the strength and abrasion resistance of the sandstone aggregates to increase towards the central part of the outcrop, reflecting the regional trend of increased compression towards the axis of the main Coalfield syncline. The strongest Pennant sandstone aggregates would, therefore, generally be expected in the Rhondda Valley area (Adlam, 1984).

The main sandstones units within the Pennant Measures are shown on the map and resources are extremely large. Current quarrying operations are located in the Brithdir Beds, the Hughes Beds and the Grovesend Beds. However, the different formations within the Pennant Measures have not been separately distinguished because the sandstones are, in general, very uniform in both their lithology and aggregate properties, irrespective of their stratigraphical position. The main geological constraints on resource development are the degree of weathering, the occurrence and proportion of interbedded mudstones, and the nature and extent of any overburden. Most of the production is sold for roadstone, particularly wearing course materials in demanding highway conditions, where the properties of high polish resistance, high strength and resistance to abrasion are required.

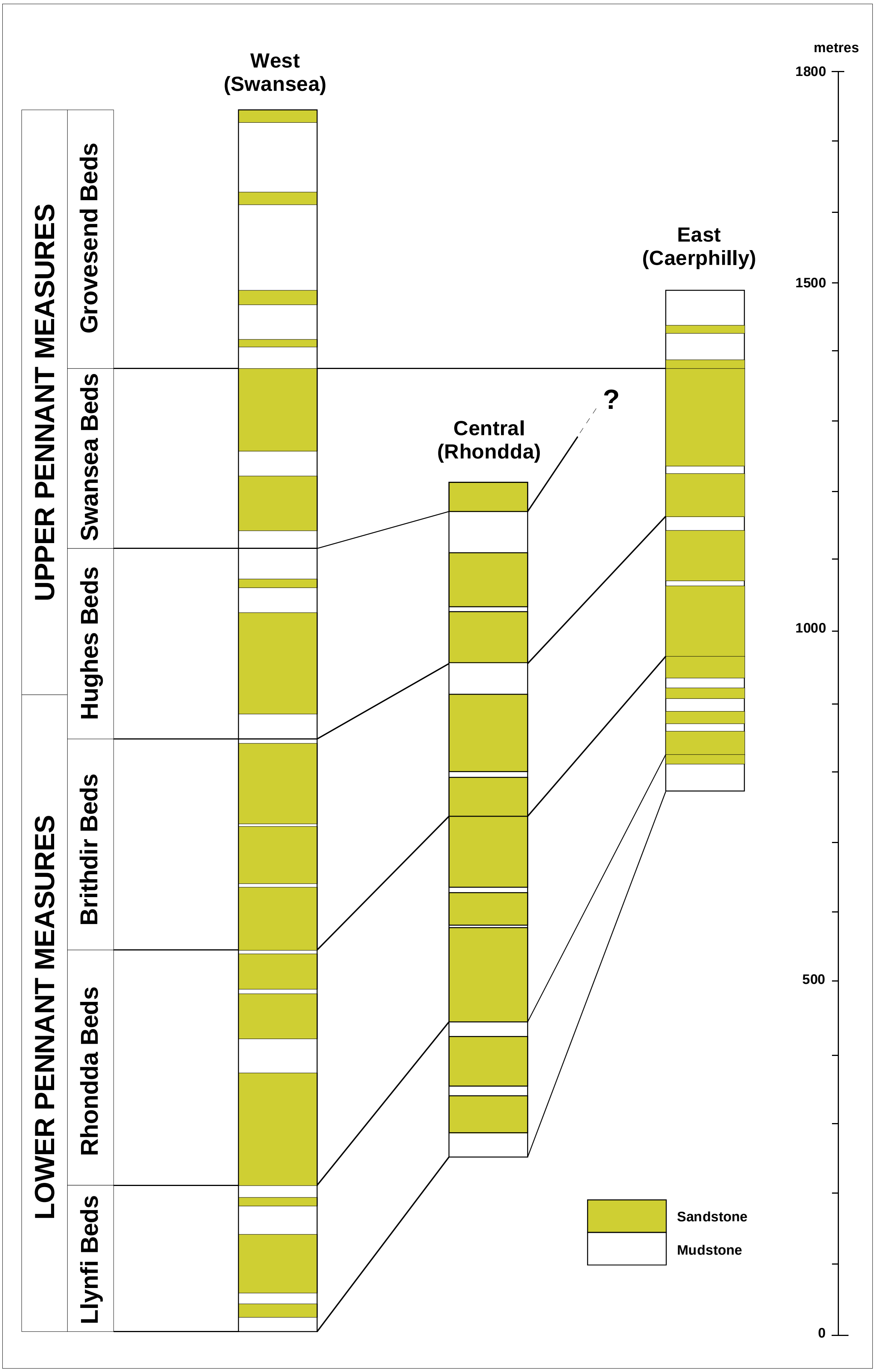


Figure 5 Schematic drawing to show variation in the Pennant Measures of the South Wales Coalfield

The sandstones are primarily valued for their high skid resistance (high PSVs) and for this reason a large proportion of the output is exported to other regions. The high PSV market is relatively limited in total.

Drybrook Sandstone, Millstone Grit, Lower and Middle Coal Measure sandstones
Sandstones are poorly developed within the shale and mudstone-dominated sequences of the Millstone Grit and Lower and Middle Coal Measures which crop out around the rim of the South Wales Coalfield. The sandstones are often thin and laterally impersistent and are flaggy to massively bedded, fine to coarse-grained, quartzitic sandstones (orthoquartzites), locally with conglomerate beds or micaceous sandstones. The extent of the main sandstone units, including the Drybrook Sandstone (Lower Carboniferous) in the Chepstow area, is shown on the map. The Millstone Grit generally consists of two lithological divisions, an impersistent basal sandstone and conglomerate group up to 120 m thick which is overlain by mudstones. The lower sandy division is characterised by thick, cross-bedded, well-cemented sandstones and grits in units up to 60 m thick separated by thinner sequences of mudstone and siltstone. These sandstones crop out extensively along the northern flank of the South Wales Coalfield but are thin or absent along the southern and eastern flanks of the Coalfield.

The principal outcrop of sandstone in the Lower Coal Measures occurs near the base of the Coal Measures sequence on the northern flank of the Coalfield. This sandstone, termed the Farewell Rock, is a massive, quartzitic sandstone with a maximum thickness of almost 60 m. Other sandstone units within the Lower and Middle Coal Measures are thin or are highly variable in thickness. They pass laterally into mudstones or siltstones.

The sandstones of the Millstone Grit, and Lower and Middle Coal Measures have in the past provided a source of building stone and aggregates. The Millstone Grit on the northern flank of the Coalfield has also been extensively worked as a source of silica rock for the manufacture of the silica refractories (see below) and numerous disused quarries mark the outcrop. The last working quarry extracting building stone from Lower Coal Measures sandstones (Cefn Cribbwr Sandstone) near Bridgend is worked intermittently.

The quartzitic sandstones can be expected to produce strong and durable aggregates but their monomineralic nature (orthoquartzites) would probably result in only moderate PSVs (i.e. the aggregates will tend to produce a more easily polished surface) well below the values typical of Pennant sandstone. The coarser-grained sandstones and conglomerates are generally weaker (AIVs >30) but are very durable. The two lithologies are commonly interbedded, downgrading the potential of the resource. Nevertheless the quartzitic sandstones of the Lower and Middle Coal Measures and Millstone Grit are a potential source of aggregates, although not suitable for the most demanding applications (i.e. road surfacing). They may be up to 100 m or so in thickness and some outcrops are sufficiently large to support a modern quarrying operation. That they are not worked is due to the local availability of alternative resources (Carboniferous limestone, Pennant sandstone).

Late Ordovician and early Silurian sandstones

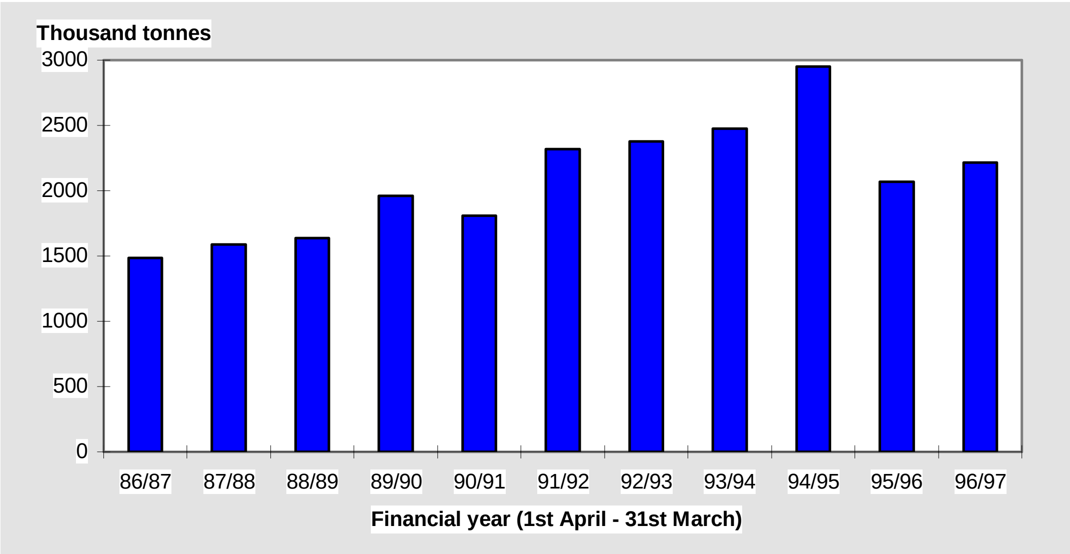
Localised developments of sandstones (mainly greywackes) interbedded with mudstones occur in a dominantly mudstone succession of late Ordovician to early Silurian age to the north-west of the Afon Tywi. Some of the sandstones exhibit moderately high PSVs (62) and are suitable for use as road-surfacing aggregates and are worked on a small-scale near Llansawel and to the north of Carmarthen. Their economic potential is limited, however, by their impersistent nature, the variable nature of the strata and remoteness from major aggregate markets. Due to the lack of modern geological maps for much of the area north-west of the Afon Tywi, the distribution of these sandstones is largely unknown. As such, the distribution of these rocks shown on the map is based on the data available to date. The distribution of the most important unit, the late Ordovician 'Bala Series Grits' is largely unknown, but has been shown schematically in proximity to existing quarries.

In South Wales sandstones younger than the Carboniferous are too soft and porous to be used as sources of aggregates, other than as a source of fill, and are not shown on the map. Sandstones within the Devonian (Old Red Sandstone) are very variable in composition and properties, and mainly occur in the upper part of the sequence. They have been worked in the past as a source of building stone. The sandstones of the Senni Beds, which have an extensive outcrop in the Brecon Beacons and Black Mountains, were identified as a potential source of high specification aggregate in the Travers Morgan report (Thompson et al, 1993). However, this assessment was based on very limited data of this highly variable sequence and as the Senni Beds have not been worked commercially, except on a minor scale for building stone and fill, they and other sandstones of Devonian age, have been excluded from the map. Only one small quarry is operating in the Old Red Sandstone, for building stone (Appendix 1).

COAL

South Wales was formerly one of Britain's most productive coalfields and the principal source of coal exports. Peak production was achieved in 1913 when 57.9 million tonnes were mined from over 600 collieries. The number of collieries decreased to 329 in 1944 and 80 in 1967 before a rapid decline led to the closure of all deep shaft mines at the time of privatisation of British Coal in 1994, except for Tower Colliery, Hirwaun, which was kept open by a miners' buyout. There are currently 26 operating underground mines in the coalfield which vary in size from large collieries (such as Tower) to small drift mines employing only a few miners. The three principal drift mines are Betws, Aberpergwm and Pentreclwydau South, but small-scale mining from drifts and adits has always played a traditional role in the coalfield.

Opencast coal mining began during the Second World War and is now the major source of coal. There are currently some 14 producing sites. Coal output for the year to the end of March 1997 was 2,270,000 tonnes of opencast coal and 889,737 tonnes of deep-mined coal (Figure 6).



Source: Opencast Coal Mining Statistics, County Planning Officers Society, and The Coal Authority

Figure 6 Opencast coal production in South Wales, 1986–1997.

Opencast activity has been largely confined to the exposed Lower and Middle Coal Measures which crop out around the periphery of the coalfield. Low dips on the north crop of the coalfield result in conditions amenable to large scale opencast extraction. The cover of thick Pennant sandstone in the central tract of the coalfield, together with the steep-sided, deeply incised valleys, precludes major opencast activity in much of this area.

Structurally, the coalfield is a broad, asymmetric east–west - trending syncline. Structures are highly complex on the south and north-west outcrops, with much thrust faulting. Even in areas of relatively simple structure, the abundance of small-scale faults created problems for underground mechanised long-wall mining.

The main concentration of coals of current economic interest lies between and includes the Five Feet-Gellideg and Two Feet Nine seams (Figure 7). Deep mining was traditionally concentrated on the seams in this interval (Five Feet, Gellideg, Seven Feet, Bute, Nine Feet, Six Feet, Four Feet, Two Feet Nine). However, many other seams, particularly in the interval from the Two Feet Nine up to the Brithdir, have been mined, largely from surface adits and drifts, as well as by opencasting. In addition, coals higher in the Pennant (Upper Coal) Measures have been small-scale mined and opencasted and continue to constitute a mineable resource. The lower boundary of opencast coal resources is defined in this study as the outcrop of the Garw, although a few thin coals below may be of local interest and one of these (the Lynch) is taken as the lower limit in the Swansea district.

The base of the thick development of Pennant sandstones is generally taken as the upper limit of opencastable resources shown on the Coal Resource Map. This lies at the Brithdir in the east of the coalfield, falling to the

No 2 Rhondda in the west. However, the return of coal-bearing facies in the upper part of the Pennant Measures, with several thick coals, results in outliers and strips of opencastable resources.

The coals have generally low sulphur values, the average total sulphur content of the main producing seams being about 1 per cent compared with 1.6 per cent for Britain as a whole. Higher sulphur contents are found in the coals of the Pennant Measures, as well as in the seams which underlie the marine bands.

Figure 7 gives two generalised sections of the Coal Measures of the South Wales Coalfield. They show the thinning of the Coal Measures succession from west to east across the coalfield. The rank of the coal, that is the degree of coalification, increases north-westwards, from bituminous, high volatile coals in the east to anthracites (with less than 8 per cent volatiles) in the north-west. These anthracites are the only important anthracite resource in Britain. The cause of the high geothermal gradient which produced them remains the subject of debate. The heating, which predated the folding of the strata, may have been caused by one or more factors such as depth of burial, intrusion of granite at depth, or fluxing of hot, hydrothermal fluids.

Opencast coal resources

The opencast resources shown on the accompanying Coal Resource Map are divided into two resource zones. These zones define areas within which coals of potential economic interest may occur. This potential is not uniform but depends on many factors, including coal quality and coal to overburden ratios at specific sites.

A primary resource area (Zone 1) constitutes the main target for opencast coal extraction and has been much exploited in the last thirty years. It comprises a closely spaced succession of thick coals, from the Gellideg and its correlatives at the base to the Two Feet Nine and its correlatives at the top. Where these two coals are thin or unmapped, the boundaries of the zone are placed at the thickest overlying (in the case of the Gellideg) and underlying (in the case of the Two Feet Nine) coals respectively. Details of the zone boundaries are given in Appendix 4 and shown on Figure 7.

A secondary resource zone (Zone 2) represents the areas which contain opencast coal resources, but in which the coals are generally thinner and less concentrated in vertical and areal distribution. Nevertheless, the zone constitutes an important resource and its coals have been exploited and continue to be worked, albeit on a smaller scale than the primary area coals. The zone spans several stratigraphical intervals. The lowest lies between the Garw and the Gellideg coals and their correlatives. The Garw is the only coal in this interval. Lower coals are mainly thin, except in the Swansea area, where the Lynch Coal is taken as the base of the resource zone. The main secondary resource area lies between the Two Feet Nine and its correlatives and the base of the thick Pennant sandstones of the Upper Coal Measures. Small areas of Zone 2 resources occur within the Upper Coal Measures. These are zones where generally small areas of coal have mudstone roofs and may be extractable by opencast mining. Smaller areas of thin locally extractable coal may lie outwith these zones.

The areas of opencast resources include those where coal-bearing strata crop out in the bottoms of the main South Wales valleys. There, they are extensively covered by superficial alluvial, glacial, glaciofluvial and landslip deposits, as well as urban development, which would preclude their exploitation. Similarly, the resources in the coastal areas are buried below drift deposits, and locally the resource area is covered by Triassic strata on the southern crop of the coalfield.

Areas of opencast and deep mine coal extraction

The Coal Authority is a Non-Departmental Public Body which was established by the Coal Industry Act 1994. On 31st October 1994 it assumed responsibility for all the interests previously vested in British Coal in respect of unworked coal and coal mines and for the liabilities associated with past coal mining and unworked coal. The main functions of the Authority are to manage the coal resources under its control, encourage economically viable operations to work these resources, grant licences for coal exploration and extraction, provide effective management of subsidence damage claims, and provide information on past, present and proposed future coal mining activities.

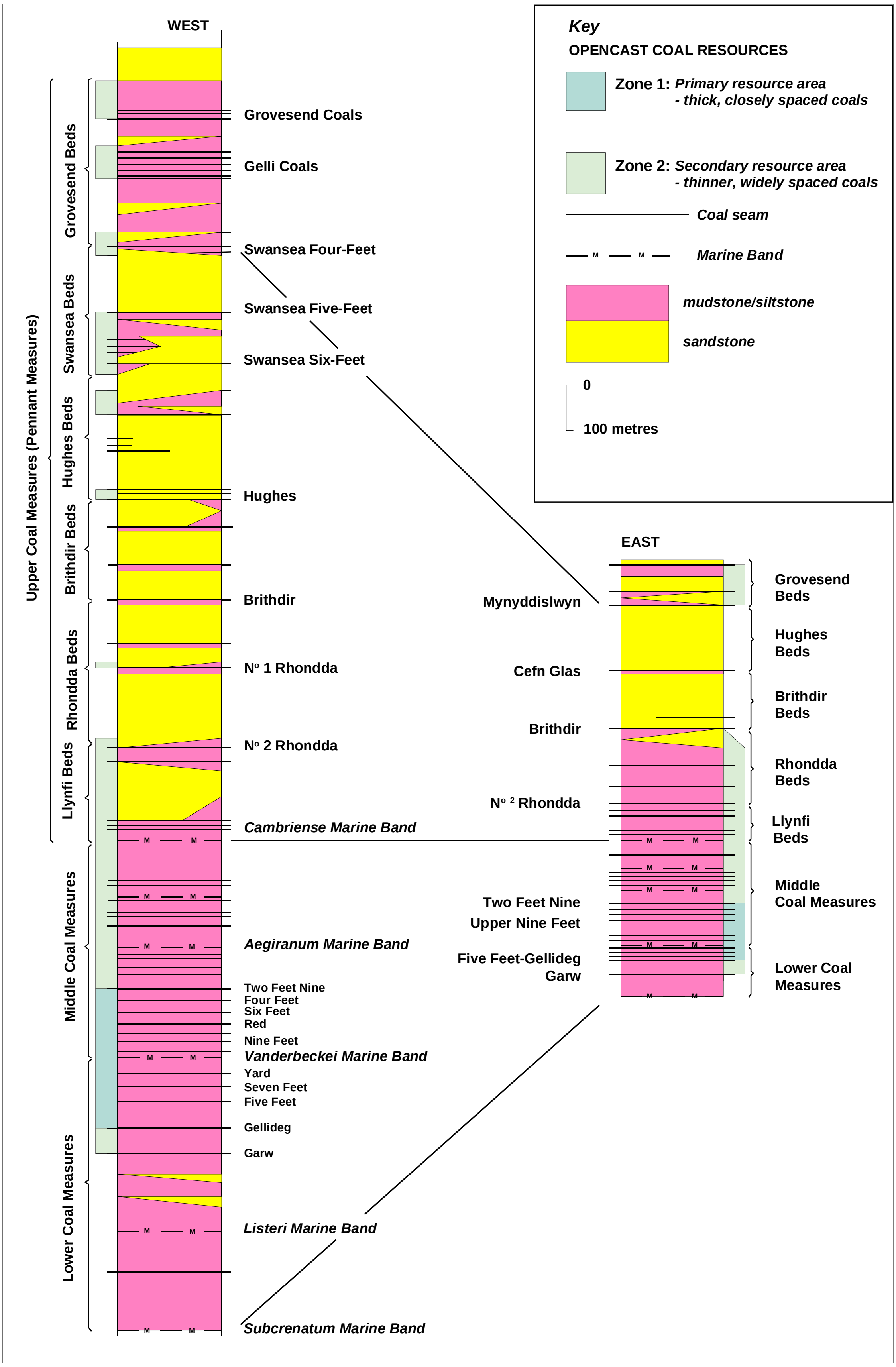


Figure 7 Generalised vertical sections of the Coal Measures succession of the South Wales Coalfield

For currently active sites, the extent of the licence area for coal extraction issued by the Coal Authority is shown and a distinction is made on the map between deep mine and opencast licences. Comprehensive information on areas of extracted opencast coal is not available. BGS 1:50 000 maps show extracted areas up to the date of the survey of the component 1:10 000 or 1:10 560 sheet on which the site lies, but these are now over 25 years old. Completion plans prepared by British Coal Opencast, and their successors, are lodged with the BGS records archive, although the coverage is incomplete. The Coal Authority's Mining Reports database contains information on past opencast coal mining activity which is an aggregate of information derived from a number of sources. The areas of former opencast coal sites shown on the map principally reflect site boundaries, although in some instances only the limits of coal extraction may be shown. The area of actual coal extraction usually represents only a part of these sites. No claim is made for the accuracy and completeness of this information. More detailed information on specific sites may be obtained from the Coal Authority (Appendix 2).

The extensive nature of these former opencast coal sites does not imply that the coal resource has been exhausted. The economics of coal extraction have changed with time, allowing coals with higher overburden ratios to be extracted. Some sites, or parts of sites, have been worked on more than one occasion and may be worked for deeper coal in the future. However, modern sites worked within the last 20 years are likely to have exhausted the currently economically recoverable coal resources. Extensive areas of the coalfield have been worked by deep mining but these are not shown on the map. This information may be obtained from the Coal Authority. Some areas of deep coal resources also remain which are of economic interest.

OIL AND GAS

The major factors which have a bearing on the hydrocarbon potential of the South Wales Coalfield and surrounding areas, and on the coalbed methane prospectivity of the coalfield are summarised below.

Conventional hydrocarbon

Source rocks and their maturity

There are several potential gas-generating source rocks. The Coal Measures, which contain coals up to anthracite rank, occur at maximum depths of approximately 2 km in the western part of the South Wales Coalfield, between Llanelli and Swansea. The high rank of the coals indicates that they have undoubtedly generated large quantities of gas. However, the coals in the South Wales Coalfield are thought to have achieved their present rank at the end of Carboniferous times, and the coals are unlikely to have generated gas since. There has been an extremely long period (about 290 million years) during which any free gas trapped at end of Carboniferous times could have escaped. The current temperature of the coals is estimated to be around 60°C or less, too low to generate gas.

Mudstones within the Millstone Grit occur beneath the South Wales Coalfield. Their source potential is not known but is probably limited. They too would have reached their maximum maturity at around 290 million years before present. They are at a maximum temperature of around 80°C at present, and so are not sufficiently hot to generate oil or gas.

Outside, and possibly beneath, the South Wales Coalfield, late Cambrian mudstones have been considered as potential source rocks for gas and potential pre-Carboniferous reservoirs occur above these source rocks. This prospect was tested by the Usk 1 borehole, drilled in 1988, but the well was abandoned with gas shows.

Reservoirs, traps and seals

Sandstones within the Coal Measures and the underlying Millstone Grit strata could have provided reservoirs for gas. The South Wales Coalfield as a whole consists of a major syncline, however, fault-bounded traps, and numerous smaller anticlines and synclines superimposed on this broad structure, could have formed traps for gas generated from the coals. Seals to the sandstone reservoirs would likely have been provided by the interbedded mudstones in the Coal Measures and Millstone Grit. However, although minor gas accumulations have been found in sandstones during coal mining and associated drilling, no substantial gas deposits have yet been discovered. This might be because of gradual leakage since gas generation ceased, as there is extensive faulting in the South Wales Coalfield which could have breached the seals to any traps.

Exploration

Three wells have been drilled to test the conventional oil and gas prospects of the South Wales Coalfield and underlying rocks (see inset on the Coal Resources Map); Pontypridd (Anglo-American Oil Co Ltd, 1942), Senghenydd (Cambrian Exploration Ltd, 1972), and Maesteg (Cambrian Exploration Ltd, 1973). No shows were encountered in any of these wells. Additionally, large numbers of boreholes drilled for coal exploration and development, and extensive mining, have failed to encounter any economically significant accumulations of oil or gas. Thus the South Wales Coalfield is not generally considered to be prospective for conventional oil and gas.

Outside the South Wales Coalfield the Usk 1 (Sovereign Exploration Ltd) well was drilled in 1988. Although the gas potential of late Cambrian strata was proved, no adequate reservoirs were encountered (Butler and others, 1997). The licence was subsequently relinquished, downgrading the hydrocarbon prospects in the area surrounding the South Wales Coalfield.

The conventional hydrocarbon potential of South Wales is low. It is possible that further exploration wells may be drilled, as at least some of the factors needed for success are present. However, unless a discovery is made, there is unlikely to be an upturn in the very low levels of activity seen since the 1940s.

Coalbed methane

The South Wales Coalfield is prospective for coalbed methane and much of the coalfield is licensed for exploration. The coalfield has the highest coalbed gas levels of any in Britain, with average gas contents of 13.3 m^3/tonne (Creedy, 1986; 1991) and values reaching as much as 20 m^3/tonne in the anthracite belt. Contoured methane values (m^3/tonne) redrawn from Creedy (1986) are shown on the map. Mine gas has been produced and utilised over the years, but the only coalbed methane exploration well drilled to date, Margam Forest 1, was plugged and abandoned as a dry hole in 1996. Further information from the well is confidential.

The main target sequence is likely to be within the Lower and Middle Coal Measures, between the Five Feet-Gellideg and the Two Feet Nine coals. This sequence thickens from about 80 m in the east of the coalfield to about 300 m in the west. The total thickness of coal in the target sequence is likely to be about 12–25 m. Despite the disappointing results from the Margam Forest well, at the present stage of exploration the entire area of the coalfield where the target seams are covered by around 400 m or more of overburden are considered to have potential. This potential will be lower in areas where there has been extensive mining and associated degassing of the seams (Glover and others, 1993).

Given the high gas content of the coal seams, the factor most critical to the establishment of successful production is likely to be the permeability of the coal seams. Elsewhere in Britain, this has proved to be the stumbling block to the establishment of successful production.

CLAY AND SHALE, INCLUDING FIRECLAY

Clay and shale are used mainly in the manufacture of structural clay products, such as facing and engineering bricks, pavers, clay tiles and vitrified clay pipes. Brick manufacture is the largest tonnage use. Clay and shale are also used in cement manufacture, as a source of constructional fill and for lining and sealing landfill sites. The suitability of a clay for the manufacture of structural clay products depends principally on its behaviour during shaping, drying and, most importantly, firing. This behaviour will dictate the final properties of the brick, including its aesthetic qualities.

Small brickworks mainly producing 'common' bricks from locally won raw materials were formerly a common feature in many industrial areas of Britain. However, in the last two or three decades there has been a major rationalisation of the brick industry which is now based on a small number of plants operated by a limited number of companies. With the demise of the 'common' brick, the main products are now high-quality facing bricks, engineering bricks and related products such as clay pavers. Modern brickmaking technology, which requires high capital investment, is increasingly dependent on raw materials with predictable and consistent firing characteristics in order to achieve high yields of saleable products. Blending different clays to achieve improved durability and a range of fired colours and aesthetic qualities is an increasingly common feature of the brick industry.

Clay and shale resources occur extensively in South Wales and brick manufacture in the past has been based on Devonian mudstones, Carboniferous mudstones and fireclays, Triassic mudstones and glacial clays. The Triassic Mercia Mudstone was extracted to the south-west of Cardiff until the early 1970s and both colliery spoil and waste from ironstone mining have also been used in brick manufacture in the past. Today there is only one brick factory in South Wales, which is the Emlyn Works at Pen-y-Groes in Carmarthenshire. Brick production was formerly based on colliery spoil but a high soluble sulphate content gave rise to efflorescence problems. In recent years, production of facing bricks and clay pavers has been based on both boulder clay and mudstone from the Middle Coal Measures and fireclays imported from local opencast coal sites. Fireclays typically have relatively low iron contents, compared with other brickmaking clays and are used in the production of buff-coloured bricks. The suitability of both Coal Measures mudstones and fireclays for brick manufacture depend principally on their carbon content, absolute levels depending on the firing characteristics of the clay and the kiln.

Fireclays typically occur beneath coal seams and thus resources are confined to coal-bearing strata. Historically fireclays were valued as refractory raw materials, because of their relatively high alumina contents. Demand for fireclay has declined markedly since the late-1950s, most notably due to changing technology in the iron and steel industry where more severe operating conditions now require higher quality refractories. However, fireclays with low carbon and iron contents are now valued for the manufacture of facing bricks. The South Wales Coalfield was never an important source of fireclay overall but mining was concentrated in two areas. In the Pontypool area several fireclays in the Lower and Middle Coal Measures were formerly worked, the last mine closing in the late-1960s, and in the Llanelli area where production based on the Upper Coal Measures ceased in the late 1970s. There has been no fireclay mining in South Wales since then. Until the advent of opencast coal mining during the Second World War, fireclay was produced almost entirely by underground mining. Fireclay mining declined rapidly thereafter and today production is almost entirely as a by-product of opencast coal mining. Both fireclay and mudstones occur in association with opencast coal with which they may be worked. However, this is only rarely the case because of their highly variable quality, and for operational and/or planning reasons.

Clay accounts for some 10–15 per cent of the feed for the manufacture of cement, providing most of the silica, alumina and iron oxides necessary for the formation of cement clinker. At the Aberthaw cement works, the clay component of the feed is provided by mudstones interbedded with Jurassic limestones.

SILICA ROCK

Silica rock consisting of monomineralic quartzites and quartzitic sandstones was formerly an important refractory raw material and indeed the first significant production of silica bricks was from the Millstone Grit of South Wales (the Dinas Rock of the Vale of Neath) in 1856. Rapid changes in refractory and steelmaking technology, and in particular the replacement of the open hearth furnace by basic oxygen steelmaking and electric arc furnaces, has resulted in a rapid decline in demand for silica refractories since the late-1950s. Manufacture of silica refractories has now ceased in Britain. The requirements for silica rock for refractory manufacture were a high silica content (>97 per cent), together with low alumina and alkalis and a hard rock with a high bulk density and low porosity. The latter properties also make silica rock suitable for aggregate use (see Sandstone).

The Basal Grit of the Millstone Grit of South Wales cropping out on the northern flank of the South Wales Coalfield was formerly the most important source of silica rock in Britain. Selective quarrying and underground mining was required to overcome variations in quality but the best grades of stone contained up to 98.8 per cent SiO_2 and between 0.3 and 0.5 per cent Al_2O_3. Former producing areas were on Mynydd-y-Garreg near Kidwelly; Allt-y-Garn near Carmel; Cennen in the Black Mountains north of Glanaman, and Cefn Cadlan near Penderyn, with mining in the area between Penderyn and Glyn-neath. The Basal Grit consists of a variable succession of quartzite and quartzitic sandstones, with thin quartz conglomerate beds and occasional interbedded mudstones. In places quartzose sands have been formed by the solution of the siliceous cement. West of the Vale of Neath, in the Brecon Beacons National Park, large-scale collapse of the Basal Grit into solution-enlarged fissures and caves in the underlying Carboniferous Limestone has produced saucer-shaped accumulations of silica sand and siliceous clays. Some of the sands are of high purity (99 per cent SiO_2) and have been worked in the past. Their possible use for glassmaking has been considered but they are relatively inaccessible and somewhat variable in composition. White or yellowish-brown siliceous clays (Plastic Clay Beds) underlie the Basal Grit west of Llandybie. These were formerly worked at Allt-y-Garn for refractory use. Following the decline in the use of the Basal Grit for refractory purposes it has been worked for aggregate use.

METALLIFEROUS MINERALS

The area lies on the edge of the Central Wales Orefield and small occurrences of non-ferrous metals are widespread in Carmarthenshire and at least two major mines were in operation, Ogofau or Pumpsaint [SN 664 402] gold mine and Nantymwyn [SN 784 446] lead mine (Foster Smith, 1981: Hall, 1971).

At Ogofau (Dolaucothi, Pumpsaint or Roman Deep), auriferous quartz, pyrite and arsenopyrite, with galena and sphalerite, are hosted in late Ordovician and Silurian rocks (Annells and Burnham, 1986). The deposits were extensively worked during Roman times, mainly from open pits, but some underground working was also carried out. The mine was rediscovered in 1844 and between then and 1912 a number of small-scale attempts were made to mine gold-bearing quartz veins. The mine (then known as Roman Deep) was again worked by underground methods during the 1930s, with some 20,000 tonnes of ore with a grade of 0.2 oz/tonne being produced. The mine is currently a tourist attraction, but there is still interest in the gold potential of the area.

In Carmarthenshire, lead-zinc mineralisation, with minor barytes, occurs infilling fissure-veins in Ordovician rocks. Small amounts of ore have been raised, the largest output being at Nantymwyn where some 80,000 tonnes of lead ore is reported to have been produced between 1775 and 1900 (Hall, 1971). The mine was last worked in 1932 and had ‘proven reserves’ of some 209,000 tonnes lead-zinc ore. Vein-style mineralisation is unlikely to be of economic interest in the future.

The sideritic ironstones of the Lower and Middle Coal Measures provided the raw material for the development of the iron and steel industry in South Wales during the late 18th and 19th centuries. These deposits are no longer of economic significance.

Replacement deposits of iron ore (mainly goethite) occur in Carboniferous limestones where they crop out along the southern edge of the coalfield, and were worked in a 13 km belt between Llanharry and Taff’s Well. The deposits occur at, or below, the unconformity between the Triassic and the underlying junction of the Carboniferous Limestone and Millstone Grit and extend down dip within the limestones. Mining dates back to Roman times and the total output from the field was some 10 million tonnes. The Llanharry mine, where the ore graded 48 per cent Fe, was the last to close in 1974. Resources are now exhausted. Minor base-metal working took place on the Carboniferous Limestone and Millstone Grit outcrop during the 19th century.

IGNEOUS ROCK

Igneous rocks have a very limited distribution within the area. They occur as isolated bodies of both intrusive and extrusive (volcanic) igneous rocks, which are shown separately on the map. Extrusive rocks, such as lavas and tuffs, may be weathered and more variable in composition than their intrusive equivalents and are rarely of economic importance. In the extreme west of the area, on the eastern end of the Prescelly Hills, intrusive sheets of dolerite occur within Ordovician strata. These have been worked at Garn Wen on an intermittent basis for local use as roadstone. At Llangynog, to the south-west of Carmarthen, two small faulted-bounded areas contain Precambrian volcanic rocks. They comprise 400 m of rhyolite lavas overlain by 700 m of volcaniclastic sediments and basalts. The sequence is locally intruded by dolerite sheets. Only the rhyolites and dolerites are shown on the map although these have not been worked. However, just to the north a small dolerite intrusion was formerly worked on a small scale for roadstone.

A very small volcanic vent and associated dyke some 6 km south-east of Usk has been excluded from the map.

SLATE

Areas which have yielded slate suitable for roofing and other commercial purposes have a very restricted distribution and are confined to the extreme western part of the region which forms part of the Prescelly slate belt. These resources have not been worked on any scale for many years, but minor production continues intermittently at the Gilfach quarry, near Llangolman.

SAND AND GRAVEL

Resources of sand and gravel in South Wales are limited and extraction has, historically, been on a very small scale. Current production within the study area is probably less than 40 000 t/y. Marine-dredged aggregates derived from the Bristol Channel, and consisting almost entirely of sand (about 1.5 million tonnes in 1995), account for most of the fine aggregate consumed (excluding material for the Cardiff barrage). Fine aggregate is also imported from adjoining areas in England and derived from crushed rock fines produced at aggregate quarries. Coarse aggregate is primarily provided by crushed rock (see Limestone, Sandstone).

Bristol Channel

The Bristol Channel is a major source of marine-dredged aggregates, principally sand. The area forms a wide shallow estuary with a large tidal range and strong currents. Sediment up to sand grade is mobile over the tidal cycle and this has led to the sand grade sediment being well sorted and formed into a variety of bed forms. Sand resources tend to occur in clearly defined linear sand banks and extensive sandwave fields. The major sand bodies such as the Holm Sand, Culver Sand, Nash Sand, Hugo Bank and Helwick Bank are of variable thickness but are mostly up to 10 m thick. Several banks rise some 20 m above the surrounding seabed and contain substantial accumulations. Some of the sand is too fine for aggregate use and some deposits, e.g. Cardiff Grounds, are contaminated with coal particles. There are, nevertheless, extensive resources of medium-grained sand suitable for use as fine aggregate. Gravel resources are minimal, despite relatively large areas of gravel lag deposits. These deposits, however, are very thin and of patchy distribution.

Concern has been expressed about continued dredging in the Bristol Channel and a research project has recently been commissioned by the DETR and Welsh Office. The project is being undertaken by Posford Duvivier and is entitled ‘Bristol Channel, Marine Aggregates: Resources and Constraints Study’. The principal objectives are (a) to study the quality and quantity of resources to determine the extent that production can be maintained; (b) to assess sediment processes to establish whether extraction is either diverting material from beaches or that the banks are not being replenished, causing draw down of beach sand and increased coastal erosion; and (c) an environmental assessment relating to impacts within the Channel and on the beaches. This work may stimulate increased interest in the potential of onshore resources in the future.

Onshore resources

Information on the onshore sand and gravel resources of the region is available in reconnaissance studies carried by BGS (James and Thornton, 1983) for south-east Glamorgan and Gwent and reconnaissance studies have also been undertaken by the BGS in the Bridgend area (Wilson and Smith, 1985). Recently the BGS has mapped the sand and gravel resources in Carmarthenshire as part of the Afon Teifi Catchment Survey. A regional assessment, including the current project area, has been undertaken by the University of Liverpool (Crimes and others, 1992) on behalf of the Department of the Environment and the Welsh Office. That project assessed available geological data contained in BGS maps and memoirs, and in other relevant literature, carried out mapping, evaluated available borehole data, including carrying out limited drilling, and provided a broad appraisal of the sand and gravel potential of the region.

A number of relatively large areas of sand and gravel were identified (Pontardulais, Abergavenny, Pendine, Pembrey, Swansea Valley, Vale of Neath, Cardiff–Bridgend, Llandovery, Lampeter and Brecon) of which the Abergavenny area adjacent to the valley of the River Usk has the greatest potential. There has, however, been only limited commercial exploration. Where resources do occur, they are severely constrained by other developments, environmental designations, or are distant from major markets. Available information indicates, therefore, that the sand and gravel resources of South Wales are limited.

The variability of sand and gravel deposits means that it is more difficult to infer the location and likely extent of potentially workable resources from geological maps than for any other bulk mineral. The properties that influence this potential are the sand to gravel ratio, the proportion of fines and oversize material, the presence of deleterious rock types, such as coal and mudstone, the thickness of the deposit and its overburden, the position of the water table and the possible presence of interbedded unwanted material. Moreover, glacial sands and gravels are invariably closely associated with till (boulder clay). They may form concealed bodies either within or beneath till and may also grade into till with increasing fines content. Consequently glacial sand and gravel may be more extensive than shown on geological maps.

These variables can only be determined by drilling and geophysics, with associated particle size analysis. For these reasons the distribution of sand and gravel is not shown on the main map. The broad extent of those areas where deposits may occur are shown on the small-scale map of South Wales (Figure 8).

Onshore sand and gravel resources occur principally in superficial, or 'drift,' deposits of Quaternary age. They can be divided into three broad categories. They are:

- Wind blown/beach sands
- River gravels
- Glacial sand and gravel

Wind blown sand deposits occur in coastal belts and may be extensive and relatively thick, although the sands tend to be fine-grained, particularly away from the beach. They are usually in environmentally sensitive locations, such as at Pembrey and Pendine. However, the working of extensive dune sand deposits and the removal of beach shingle from between high and low water mark, particularly on the east side of Swansea Bay between Port Talbot and the Ogmore river, east of Porthcawl, has been a locally important source of sand in the past. Minor production of building sand from dune sand continues from Port Talbot Docks.

Post-glacial (Recent) river terraces and alluvial deposits are mainly developed along major river valleys, including the Teifi, Tywi, Usk and the valleys of the South Wales Coalfield. The composition of river gravels will reflect the nature of the bedrock and glacial units being eroded within the river's catchment. Gravels associated with the Teifi and Tywi will include weak mudstones and siltstones, in addition to sandstone derived from Lower Palaeozoic strata. In the valleys of the South Wales Coalfield the gravels will contain a high proportion of Carboniferous sandstones and quartzites, whilst those in the Usk will be dominated by Devonian sandstones. The gravels may contain a significant proportion of oversize clasts which would need to be either screened off or crushed. Some of the sandstones may be so weathered that crushing would liberate sand. In most places the sand and gravel is covered with a thin layer of overburden of silt and clay (alluvium). Significant thicknesses of sand and gravel may occur but in the Vale of Neath, the Swansea Valley and other valleys within the coalfield, resources are severely constrained by natural and developed features, e.g. narrow valleys, rivers, roads, railways, and urban and industrial development. Extensive deposits have, therefore, been sterilised. Sand and gravel has been extracted on a limited scale from river gravel deposits associated with the River Tawe in the Swansea Valley. Extensive river gravels, with river terraces and higher level fluvioglacial deposits occur in the Usk valley near Abergavenny and near Brecon. Sand and gravel has also been worked near Llandovery from the valley of the Afon Tywi and small-scale production continues in this area.

Glacial deposits include sediments laid down by a variety of glacial and fluvioglacial processes associated with ice sheets, glaciers and their meltwaters. They are likely to be variable in composition with a large amount of fines. The greatest concentration of sand and gravel is usually found in front of the maximum extent of the ice sheet or along the sides and in the floors of the major valleys through which it retreated. The limited resource potential of South Wales is due to the fact that deposits associated with the maximum extent of the glaciers now occur offshore (Crimes et al, 1992). However, an extensive suite of glacial deposits, together with river terrace and alluvial gravel deposits, occur in the Usk valley between Brecon and Usk and represent perhaps the largest resource in the region.

The Bedwin Sands, south of Caldicot, are exposed at low tide and worked as a source of fine sand.

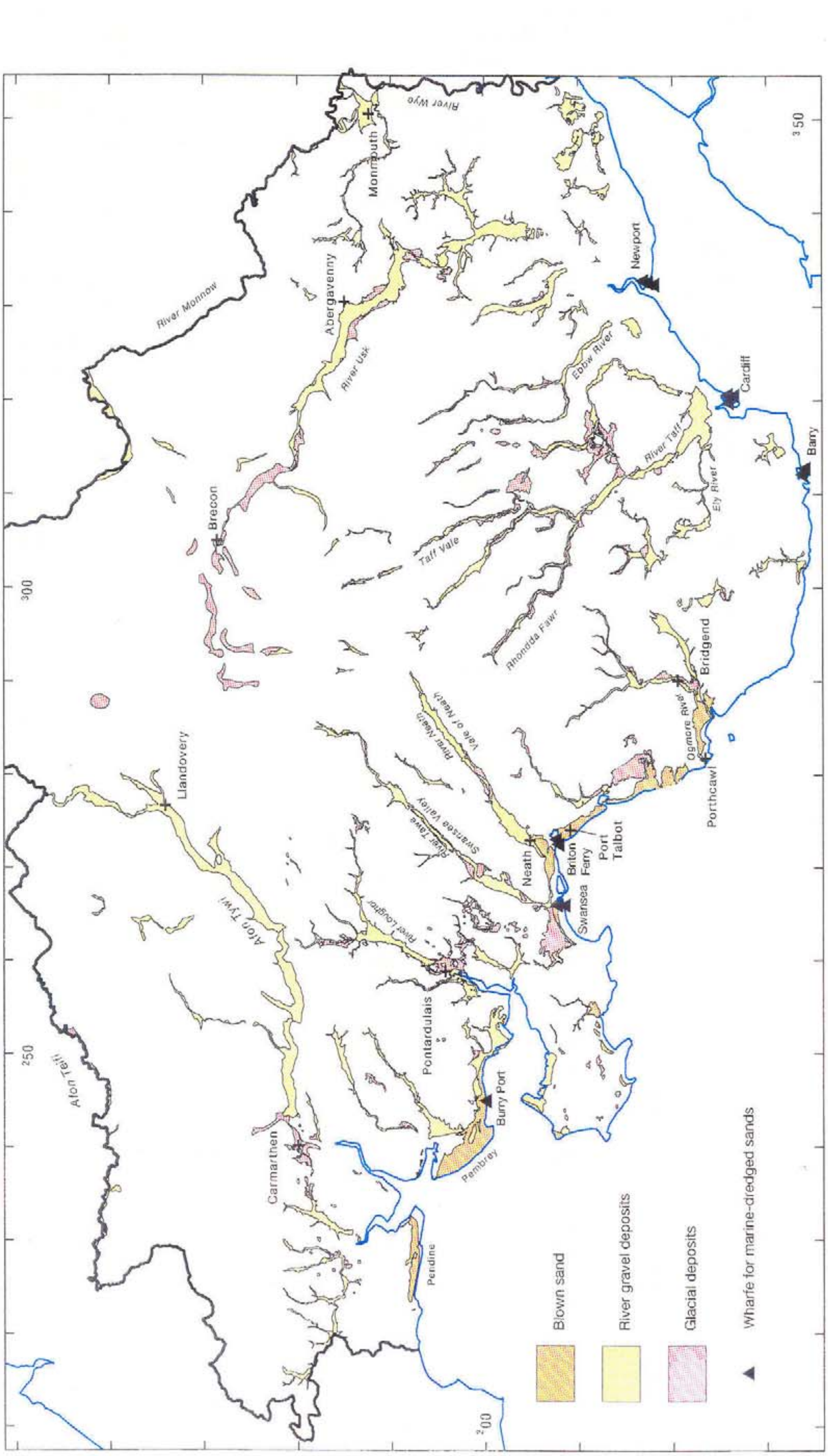


Figure 8 Simplified geological map showing distribution of sand and gravel in South Wales

SECONDARY AGGREGATES

The term 'secondary aggregates' is used to describe a range of materials which may be used for aggregate purposes (subject to considerations of quality and contamination), but which arise as wastes from a variety of activities. They may be considered under three main headings:

- Naturally-occurring materials arising from mineral extraction and processing operations, such as colliery spoil, overburden and quarry/processing waste

- Materials arising from manufacturing processes, such as slags and ash, which may be of variable composition

- Construction and demolition wastes which may be either in a natural or manufactured state and include road sub-base, concrete rubble and masonry. These materials are excluded from this study as arisings are highly variable in location, type and duration.

Utilising the aggregate potential of such materials may have the advantage of both reducing the demand for primary aggregates and the problems of disposing of waste. In general, however, secondary aggregates are only suitable for less demanding aggregate applications, and their production and use may not always be environmentally or economically desirable. Sales of secondary aggregate in 1993 are shown below (Table 8).

Table 8 Total sales of secondary aggregates in South Wales in 1993 (million tonnes).

	Roadstone	Fill/Other uses	Total
Colliery spoil	na	na	na
Slag	0.174	1.002	1.176
PFA/FBA	-	0.180	0.180
Slate/shale	-	0.074	0.074
Total	**0.174**	**1.256**	**1.430**

Source: South Wales Regional Working Party on Aggregates na not available

Colliery spoil

Colliery spoil, or minestone, is a by-product of mining and processing coal. It consists mainly of mudstones and siltstones, with some sandstones and other rock types, which occur above, below and within coal seams and which are extracted with the coal during mechanised mining. This material is removed in coal preparation plants and the separation of coal from waste is based on the higher density of the minestone. The essentially non-coal material is tipped onto spoil heaps or disposed of in lagoons, some of which may be available for potential future use if markets can be found. Some older spoil heaps consist partly of burnt spoil (red shale), a product of the internal combustion of coal and other materials in the tips. Colliery spoil in older tips, which has undergone less efficient processing, may warrant further processing to recover any remaining coal. Such operations generally do not seek to recover the spoil for aggregate use and the sites are restored following reworking.

The principal use of colliery spoil is as a low value bulk fill, mainly for road construction. However, a critical factor in the use of colliery spoil is its location with respect to markets and thus transport costs. Some colliery spoil may also be used in capping and lining waste disposal sites and for the restoration of old mineral workings. However, in these applications it is not used as an alternative to primary aggregates. With the many mine closures that have occurred in the South Wales Coalfield in recent years, the production of colliery spoil has almost ceased and the majority of sites have undergone reclamation, many using Derelict Land Grant funds. Re-working such sites for aggregate or coal may not be desirable or practicable for location or environmental reasons as many sites are situated on the tops or flanks of hills with no suitable vehicular access. Unless tip stability and /or degeneration of the restoration works is a concern, these sites are unlikely to be re-worked.

The only significant source of colliery spoil which is currently being produced is at the Tower Colliery, the largest underground mine in the coalfield. Here some 0.2 Mt/y of colliery spoil is tipped, none of which is currently utilised. Other mines do not produce significant amounts of spoil because they are less mechanised. Elsewhere the main interest in colliery spoil remains as a source of coal and several coal recovery schemes are active.

The potential use of colliery spoil is constrained by the physical and chemical properties of the material. Burnt spoil is suitable as a load-bearing bulk fill, but may be of variable quality. It tends to have a higher sulphate content and may, therefore, affect concrete if used as hardcore. Unburnt spoil, if suitably compacted, may be used for fill and hardcore and generally has a lower sulphate content. The clay content of some spoils requires consideration of placement conditions.

Blastfurnace and steel slags

Blastfurnace and steel slags are by-products of iron and steelmaking respectively and both have for many years been widely used as secondary aggregates. Blastfurnace slag in particular is one of the few sources of secondary aggregates which can be used as a direct alternative to natural aggregates for more demanding applications, notably as a road surfacing aggregate. The different types of slag vary in their physical, mechanical and chemical properties and thus their suitability for particular applications.

Blastfurnace slag is a non-metallic product consisting essentially of the silicates and alumino-silicates of lime and other bases. It is a by-product of the manufacture of iron and results from the fusion of limestone/dolomite with ash from coke and the silica and alumina-bearing residues remaining after the reduction and separation of the iron from iron ore. Slag formation performs an important function in the ironmaking process through the removal of sulphur which cannot be tolerated in the molten iron. The slag rises to the surface in the blastfurnace and is tapped periodically. Depending on the method of cooling the slag, three types of material are produced; air-cooled slag, foamed slag and granulated slag.

Air-cooled slag, which is crushed and screened, accounts for 90 to 95 per cent of all blastfurnace slag. It exhibits a crystalline structure and produces a rock-like material which is mainly used as roadstone, but also for concrete aggregate, railway ballast and as a biological filter medium. Foamed slag is produced by directing water jets onto the slag to generate steam within the slag which produces a foamed structure, suitable as a lightweight aggregate. Granulated slag is produced by cooling the molten slag more rapidly to give a slag glass which is finely ground for use in blended cements. Blastfurnace slag is produced at the Llanwern and Port Talbot steelworks in South Wales and finds a ready market, mainly as a source of roadstone.

The conversion of iron into steel involves lowering and controlling the content of impurities, such as carbon, silicon, manganese, phosphorus and sulphur, in the hot metal by removing them either as gases or incorporating them into the slag by the formation of complex oxides. This refining process is achieved by the reaction of the iron with lime (CaO) or dolime (CaO.MgO) as a flux. The composition of steel slags is complex and very variable. There are two types of steel slag - Basic Oxygen Steel (BOS) slag and Electric Arc Furnace (EAF) slag - depending on the steelmaking method used. Steel slags have a high free lime content which makes them unstable and causes expansion on contact with water. Weathering of the slag hydrates the lime and reduces the risk but it can be a time consuming process. BOS slag is produced at Llanwern and Port Talbot steelworks and some may be used, after weathering, as sub-base material. EAF slags, which have a lower free lime content, are produced at the Tremorfa Steelworks in Cardiff. After weathering for six months the material is processed for use as Type 1 sub-base. Sales are some 100 000 tonnes a year. Small amounts of EAF slag were produced at the Panteg steelworks in Cwmbran for processing at Tremorfa. The Panteg steelworks closed in January 1997. Steel slag was used on the foreshore at Tremorfa for land reclamation, and some was re-excavated in the 1980s, but the planning permission expired in 1989.

Sources of slag occur at two former steelworks in Blaenau Gwent at Ebbw Vale and Tredegar. Slag from the former is currently being used as part of a landfill operation.

Ash

All coal contains inorganic mineral matter, consisting mainly of silica and alumina derived from the mudstones and siltstones associated with coal seams. Coal-fired power stations burn pulverised coal as fuel and the main residue is a fine-grained powder called Pulverised Fuel Ash, or PFA, which is collected by electrostatic precipitators. Typically PFA accounts for some 80 per cent of all the ash produced at power stations. The remainder is produced by the agglomeration of hot ash particles which fall to the bottom of the furnace where they are collected. This material is known as Furnace Bottom Ash (FBA) and is much coarser than PFA.

The only operational coal-fired power station in South Wales is Aberthaw B operated by National Power which has a capacity of 1500 MW. The total amount of ash produced depends on how much coal is burned but typically ash production amounts to some 440 000 t/y, most of which is PFA. All the FBA, amounting to some 40 000 t/y, is sold as a lightweight aggregate for use in concrete block manufacture. Currently only some 10 per cent of the PFA is sold, primarily for bulk fill for road construction but small amounts are also used for grouting old mine workings. However, sales of PFA generally fluctuate widely from year to year as a result of particular contracts. Most of the output of PFA is landfilled on site which, subject to the necessary planning permissions, could yield some 5 million tonnes.

Two former power stations with potential sources of PFA are Llynfi, between Maesteg and Bridgend, and Uskmouth, Newport. In the former the PFA tip was partly landscaped while in the latter the PFA lagoons are still extant. There is a proposal to reopen the Uskmouth power station and to construct a new coal-fired power station at Bargoed, near Merthyr Tydfil.

Slate waste

Slate waste from former slate workings occurs at Gilfach quarry in Carmarthenshire. The material has been used as a local source of fill but usage is very small.

Quarry waste

Quarrying stone produces waste which may occur as associated weaker rock or processing fines. Some may be sold as a discrete quarry product for fill, if suitable markets can be found, or subsequently used for quarry restoration. Inactive quarries will have stockpiles of such material but of varying qualities and quantities, and the volumes involved are unknown.

MINERAL RESOURCES AND PLANNING CONSTRAINTS

The character of the landscape reflects the nature and structure of the underlying rocks, the erosive forces to which they have been subjected and the soil and vegetation that they support. It is constantly changing, due in the longer term to geomorphological processes and, in the shorter term, to economic and social pressures. Mineral extraction can cause irrecoverable, but not necessarily harmful, change to a locality over a relatively short timescale. In order to ensure that such changes are both sustainable and non-injurious to the environment, the most valuable landscapes and habitats, such as National Parks, AONBs and SSSIs, are given a greater degree of protection from mineral working. The need for mineral workings in such areas has to be justified by a most rigorous examination of the merits of the proposal. This examination should consider the public interest in the development of the resource, including the social and economic well being of the area, as well as the need to protect the environment.

Minerals extraction in areas proposed as SPA or SAC sites may be acceptable if there are no alternatives and if there are imperative reasons for the development which are of overriding public interest. For certain priority sites, development can only be considered to be acceptable due to overriding reasons of public health and safety or beneficial environmental consequences. Therefore, whilst the requirements to assess the acceptability of mineral working proposals in such designated areas may be stringent, there is no total prohibition on working minerals in such areas.

The resolution of conflicts between mineral resource development and other considerations is undertaken through the development plan framework and the development control system, and a balanced appraisal of the various issues associated with the development. The two Mineral Resources Maps of South Wales provide a synthesis of available information which can be revised and updated as additional data becomes available. In addition, additional constraint information can be incorporated as required. It is hoped that these maps, and the associated concise report, will assist local and national Government, the minerals industry and other interests in the consideration and production of policies included in development plans.

Large parts of the project area are covered by national planning designations. The area includes the Brecon Beacons National Park, within which a major proportion of the northern outcrop of Carboniferous limestone resource occurs, along with extensive areas of quartzite and areas with potential for opencast coal. Several mineral extraction operations are active within the National Park. There are also extensive areas of SSSI within the National Park, mainly located off the major mineral resource areas on the moorlands of the Black Mountain–Forest Fawr–Black Mountains, which are composed of Devonian sandstones. Less extensive SSSIs are located on limestone and quartzite resources and include sites of importance for caves and woodland.

The Gower and Wye Valley AONBs include a major proportion of the Carboniferous limestone resource of the southern outcrop and also some extensive SSSIs. Whilst the latter are principally located off the main mineral resources, such designations do coincide with limestone outcrops in a number of locations and reflect important calcareous grassland and woodland. Other SSSIs, principally related to calcareous woodland, occur on the remaining part of the southern outcrop of the limestone resource. SSSIs also cover large areas of the coastal zone, including dune systems such as Pendine and Kenfig, the cliffs of the Gower and the Vale of Glamorgan and the coastal levels from Cardiff eastwards. There are also a number of geological SSSIs, some of which are quarries. National Nature Reserves are concentrated around the Gower and in coastal areas, with a few smaller sites inland. Both the Gower and the Glamorgan coast are designated as Heritage Coast. Scheduled Monuments are widely scattered throughout the area.

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Sheet	Name	Edition	Surveyed	Published
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228	Haverfordwest	D	1903–08	1920
229	Carmarthen	S	1902–06	
	Millstone Grit and Coal Measures resurveyed		1951–56	1967
229	Carmarthen	D*	1902–06	
	Millstone Grit and Coal Measures resurveyed		1951–56	1967
230	Ammanford	S	1957–66	1977
230	Ammanford	D	1957–66	1977
231	Merthyr Tydfil	S	1966–72	1979
231	Merthyr Tydfil	D	1966–72	1979
232	Abergavenny	S+D	1968–82	1990
233	Monmouth	S+D	1933–37	1960
245	Pembroke & Linney Head	S+D	1904–09	1921
246	Worms Head	D*	1901–02	1906
247	Swansea	S	1946–54	1973
247	Swansea	D*	1946–54	1972
248	Pontypridd	S*	1945–54	1963
248	Pontypridd	D	1945–54	1960
249	Newport	S	1952–61	1968
249	Newport	D*	1952–61	1969
250	Chepstow	S+D	1937–39	1958
261/2	Bridgend	S+D	1981–83	1990
263	Cardiff	S	1967–80	1986
263	Cardiff	D	1967–80	1989
264	Bristol	S+D	1939–53	1963
		*	1:63 360 sheets	
		S	Solid edition	
		D	Drift edition	
		S+D	Solid and Drift editions combined	

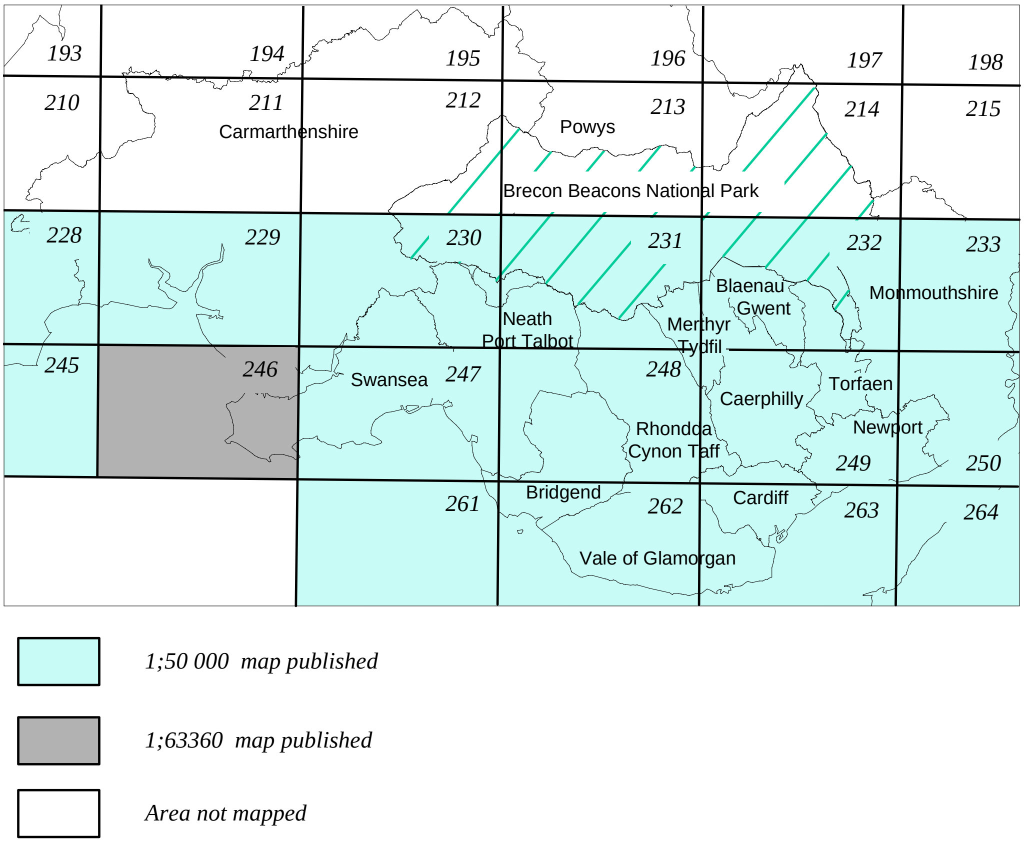

Figure 9 Availability of BGS geological map sheets

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The authors would also like to thank their colleagues in the BGS for their help, and in particular C Simpson and R Parnaby of Cartographic Services, R White and other colleagues in the Minerals Group.

APPENDIX 1 Active and temporarily inactive mineral workings in South Wales, including those used for landbank calculations. Marine and secondary aggregate workings not included

Working	***location***	***operator***	***commodity***
Brecon Beacons National Park			
Brynhenllys Revised OCCS [1]	Ystradowen	Celtic Energy Ltd	Coal
Ammanford	Llandeilo	Pioneer Aggregates	Limestone
Penderyn (Llwyn On)	Merthyr Tydfil	ARC - South Wales	Limestone
Penwyllt	Brecon	Tarmac Quarry Products (Central) Ltd	Limestone
Vaynor [2]	Merthyr Tydfil	ARC - South Wales	Limestone
Blaen Onneu			*Limestone*
Danydarren			*Limestone*
Blaenau Gwent			
Blaencuffin Colliery	Aberbeeg	K T Williams	Coal
Trefil	Trefil	Gryphon Quarries Ltd	Limestone
Bridgend			
Park Slip West OCCS [3]	Pyle	Celtic Energy Ltd	Coal
Cornelly	Cornelly	Tarmac Quarry Products (Central) Ltd	Limestone
Gaens	Cornelly	T S Rees Ltd	Limestone
Grove	Cornelly	Pioneer Aggregates	Limestone
Cefn Cribbwr	Pyle	T S Rees Ltd	Sandstone
Stormy Down			*Limestone*
Caerphilly			
Cae Glas Colliery	Fochriw	Cae Glas Colliery Co Ltd	Coal
Trecatti Landfill OCCS	Merthyr Tydfil	Ward Brothers Plant Hire Ltd	Coal
Blaengwynlais [4]	Cardiff	Tarmac Quarry Products (Central) Ltd	Limestone
Machen	Newport	ARC - South Wales	Limestone
Bryn	Nelson	Bryn Quarry Ltd	Sandstone
Hafod Fach	Abercarn	Redland Aggregates	Sandstone
Cefn Onn			*Limestone*
Cwm Leyshon			*Limestone*
Cardiff			
Blaengwynlais [4]	Cardiff	Tarmac Quarry Products (Central) Ltd	Limestone
Creigiau	Cardiff	Tarmac Quarry Products (Central) Ltd	Limestone
Taffs Well	Tongwynlais	Redland Aggregates	Limestone
Ton Mawr	Cardiff	T S Rees Ltd	Limestone
Cefn Garw			*Limestone*
Cwm-y-Fuwch			*Limestone*
Carmarthenshire			
Emlyn	Cross Hands	Castle Brick Co Ltd	Common Clay & Shale
Betws Colliery	Ammanford	Betws Anthracite Ltd	Coal
Cynheidre Colliery OCCS	Pontyates	Clay Colliery Co Ltd	Coal
Dynant Fach No 2 Colliery	Tumble	Thomas Brothers	Coal
Ffos Las OCCS	Kidwelly	Celtic Energy Ltd	Coal
Gilfach Iago OCCS	Ammanford	Celtic Energy Ltd	Coal
Blaen-y-Fan	Kidwelly	RMC Roadstone Limited - South Wales	Limestone
Cil-yr-Ychen	Llandybie	Tarmac Quarry Products (Central) Ltd	Limestone
Coygen	Laugharne	F H Gilman & Company	Limestone
Torcoed	Carmarthen	Tarmac Quarry Products (Central) Ltd	Limestone
Cilrhedin	Treneddyn		Peat
Glynsylen	Glyn Sylen		Peat
Llwynjack	Llandovery	C J Lewis	Sand & Gravel
Glyngwernen Uchaf Farm	Llanelli	Alan Rees	Sandstone

APPENDIX 1 continued:

Working	*location*	*operator*	*commodity*
Carmarthenshire continued:			
Foelfach	Conwil	Elvet Jones	Sandstone
Allt-y-Garn	Crosshands	Howard Smith	Sandstone
Dinas	Llansawel	Tarmac Quarry Products (Central) Ltd	Sandstone
Tywodfaen (Pennant)	Five Roads	Terry Davies	Sandstone
Gilfach	Clynderwen	G Davies	Slate
Crwbin			*Limestone*
Capel			*Limestone*
Castle			*Limestone*
Garn Bica			*Limestone*
Hengoed			*Limestone*
Limestone Hill			*Limestone*
Llwyn-y-fran			*Limestone*
Maesdulais			*Limestone*
Pwyllymarch			*Limestone*
Tyr Garn			*Limestone*
Penlan Farm			*Sandstone/Shale*
Capel Graig			*Sandstone/Shale*
Crosshands			*Sandstone (Silica)*
Cynghordy			*Sandstone/Shale*
Danylan			*Sandstone*
Garn			*Sandstone*
Gilfach			*Sandstone/Shale*
Nant yr Hyddod			*Sandstone/Shale*
Penyfoel			*Sandstone*
Pleasant View			*Sandstone*
Mynydd-y-Garreg			*Sandstone*
Cerrigwrwyn			*Igneous*
Garn Wen			*Igneous*
Glan Towy			*Sand & Gravel*
Merthyr Tydfil			
High Street Colliery	Bedlinog	Bedlinog Fuels	Coal
Ffynonau Duon No 3 Colliery	Rhymney	Ffynonau Duon Mines Ltd	Coal
Vaynor [2]	Merthyr Tydfil	ARC - South Wales	Limestone
Gelligaer	Trelewis	Pioneer Aggregates	Sandstone
Morlais			*Limestone*
Monmouth			
Ifton	Chepstow	ARC - South Wales	Limestone
Livox	Chepstow	ARC - South Wales	Limestone
Bedwin Sands	Severn Estuary	Severn Sands	Sand & Gravel
Neath Port Talbot			
Aberpergwm Colliery	Glynneath	Signalfern Ltd	Coal
Brawds Level OCCS	Seven Sisters	Ward Brothers Energy Ltd	Coal
Bryn-y-Garn Colliery	Seven Sisters	M & W A Fyfield	Coal
Bwlch Ton No 2 Colliery	Blaengwrach	Bwlch-Ton Mining Co (Neath) Ltd	Coal
Carn Cornel No 3 Mine	Seven Sisters	Nant Fach Mining Company Ltd	Coal
Craig-y-Llyn Colliery (II)	Glynneath	Craig y Llyn Colliery Co Ltd	Coal
Craig-y-Pant Colliery	Glynneath	Craig y Pant Colliery Co Ltd	Coal
East Pit Extension OCCS	Tairgwaith	Celtic Energy Ltd	Coal
Forest No 3 Colliery	Resolven	Signalfern Ltd	Coal

APPENDIX 1 continued:

Working	***location***	***operator***	***commodity***
Neath Port Talbot continued:			
Gleision Colliery	Ystalyfera	W H James	Coal
Henllan Uchaf OCCS [5]	Nant-y-Cafn	James & McHugh Mining Ltd	Coal
Lletty'r Crudd OCCS		C Rees and Sons Plant Hire Ltd	Coal
Nant Melyn Colliery	Seven Sisters	Signalfern Ltd	Coal
Park Slip West OCCS [2]	Pyle	Celtic Energy Ltd	Coal
Pentreclwydau South Colliery		NSM Mining (South Wales) Ltd	Coal
Pentwyn No. 3 Mine	Ystalyfera	Omri Roberts	Coal
Sarn Helen OCCS	Seven Sisters	Signalfern Ltd	Coal
Selar OCCS	Blaengwrach	Celtic Energy Ltd	Coal
Port Talbot Docks	Port Talbot	Cambrian Stone Ltd	Sand & Gravel
Cwm Nant Lleici	Pontardawe	CAMAS Aggregates	Sandstone
Gilfach	Neath	RMC Roadstone Limited - South Wales	Sandstone
Penycraig			*Sandstone*
Rheola Borrow Pit			*Sand & Gravel*
Newport			
Penhow	Newport	ARC - South Wales	Limestone
Powys			
Brynhenllys Revised OCCS [1]	Ystradowen	Celtic Energy Ltd	Coal
Henllan Uchaf OCCS [5]	Nant-y-Cafn	James & McHugh Mining Ltd	Coal
Nant Helen OCCS	Seven Sisters	Celtic Energy Ltd	Coal
Halfway	Llandovery	Forest Enterprise	Sandstone
Old Red Sandstone (Tredomen)	Llandefaelog-tre'r-graig	K Jones	Sandstone
Rhondda, Cynon Taff			
Llanilid West Revised OCCS	Pencoed	Celtic Energy Ltd	Coal
Tower Drift	Hirwaun	Goitre Tower Anthracite Ltd	Coal
Tower Colliery	Hirwaun	Goitre Tower Anthracite Ltd	Coal
Tyn y Wern Colliery	Rhigos	Signalfern Ltd	Coal
Forest Wood [6]	Pontyclun	Pioneer Aggregates	Limestone
Hendy	Cardiff	Tarmac Quarry Products (Central) Ltd	Limestone
Black Bog	Blaencwm	T Davies	Sandstone
Craig yr Hesg	Pontypridd	ARC - South Wales	Sandstone
Gelli'r Haidd Uchaf	Tonyrefail	Brunswick Developments	Sandstone
Swansea			
Barland	Bishopston	Barland Quarry Ltd	Limestone
Torfaen			
Pantygasseg Colliery	Llanhilleth	Desmond & Desmond	Coal
Blaentillery No 2 Colliery	Blaenavon	Ffynonau Duon Mines Ltd	Coal
Johnson Mine	Blaenavon	Ffynonau Duon Mines Ltd	Coal
Winstone Colliery	Blaenavon	Graig Wen Mining Company Ltd	Coal
Vale of Glamorgan			
Aberthaw	Barry	Blue Circle Industries PLC	Limestone
Forest Wood [4]	*Pontyclun*	*Pioneer Aggregates*	*Limestone*
Garwa Farm	Cowbridge	Blue Circle Industries PLC	Limestone
Lithalun	Bridgend	ARC - South Wales	Limestone
Pant	Bridgend	Tarmac	
Pantyffynnon	Cowbridge	Seth Hill & Son Ltd	Limestone
Wenvoe	Cardiff	RMC Roadstone Limited - South Wales	Limestone
Lliswerry			*Limestone*

APPENDIX 1 continued:

Working	***location***	***operator***	***commodity***
Vale of Glamorgant continued:			
St Andrews			*Limestone*
Argoed Isha			*Limestone*
Ewenny			*Limestone*
Cnap Twt			*Limestone*
Longlands			*Limestone*
Rhoose			*Limestone*
Ruthin			*Limestone*
Southerndown Road			*Limestone*

Those depicted in italic font are inactive workings where the reserves have been used for landbank calculations

Note workings shared between two Minerals Planning Authorities

[1] Brecon Beacons National Park and Powys
[2] Brecon Beacons National Park and Merthyr Tydfil
[3] Bridgend and Neath Port Talbot
[4] Caerphilly and Cardiff
[5] Neath Port Talbot and Powys
[6] Rhondda Cynon Taff and Vale of Glamorgan (reserves only in the Vale)

APPENDIX 2 Contact addresses for further enquiries

Brecon Beacons National Park Authority 7 Glamorgan Street Brecon Powys LD3 7DP Tel: 01874 624437 Fax: 01874 622574	Bridgend County Borough Council Directorate of Environmental and Planning Services PO Box 4, Civic Offices Angel Street Bridgend CF31 1LX Tel: 01656 643643 Fax: 01656 643190
Blaenau Gwent County Borough Council Planning Department 1st Floor Enterprise House Rassau Industrial Estate Rassau Ebbw Vale NP3 5SD Tel: 01495 355555 Fax: 01495 355598	Caerphilly County Borough Council Planning Division Civic Centre Pontllanfraith Blackwood NP2 2YW Tel: 01495 226622 Fax: 01495 235022
City and County of Cardiff Directorate of Planning Planning Offices Wood Street Cardiff CF1 1PS Tel: 01222 871758 Fax: 01222 871832	Carmarthenshire County Council Planning and Property Services Department 40 Spilman Street Carmarthen Carmarthenshire SA31 1LE Tel: 01267 234567 Fax: 01267 237612
Merthyr Tydfil County Borough Council Civic Centre Castle Street Merthyr Tydfil CF47 8AN Tel: 01685 725000 Fax: 01685 722146	Monmouthshire County Council Directorate of Planning and Economic Development County Hall Cwmbran NP44 2XH Tel: 01633 644644 Fax: 01633 644800
Neath Port Talbot County Borough Council Department of Planning and Economic Development Civic Centre Neath SA11 3QZ Tel: 01639 763333 Fax: 01639 764400	Newport County Borough Council Planning Services Division Directorate of Planning and Transport Civic Centre Newport South Wales NP9 4UR Tel: 01633 244491 Fax: 01633 232559

Powys County Council Planning and Economic Development Department County Hall Llandrindod Wells LD1 5LG Tel: 01597 826000 Fax: 01597 826250	Rhondda Cynon Taff County Borough Council Development Planning and Environment The Grange Tyfica Road Pontypridd CF37 2DD Tel: 01443 486801 Fax: 01443 480527
City and County of Swansea Planning Department The Guildhall Swansea SA1 4PH Tel: 01792 635710 Fax: 01792 635719	Torfaen County Borough Council Directorate of Development County Hall Cwmbran NP44 2WN Tel: 01633 648009 Fax: 01633 648017
Vale of Glamorgan Council Directorate of Economic Development, Planning, Transportation and Highways The Dock Office Barry Docks Barry CF63 4RT Tel: 01446 704600 Fax: 01446 421392	CADW Welsh Historic Monuments Crown Buildings Cathays Park Cardiff CF1 3NQ Tel: 01222 500200 Fax: 01222 826375
Minerals and Waste Planning Division Department of the Environment, Transport and the Regions Eland House Bressenden Place London SW1E 5DU Tel: 0171 890 3856 Fax: 0171 890 3859	The Coal Authority Mining Reports Office Bretby Business Park Ashby Road Burton on Trent Derbyshire DE15 0QD Tel: 01283 550606 Fax: 01283 551233
Countryside Council for Wales Plas Penrhos Bangor Gwynwdd LL57 2LQ Tel: 01248 370444 Fax: 01248 355782	The Environment Agency Welsh Regional Office Rivers House St Mellons Business Park Fortlan Road St Mellons Cardiff CF3 0LT Tel: 01222 770088 Fax: 01222 798555

Planning Services Division The Welsh Office Crown Buildings Cathays Park Cardiff CF1 3NQ Tel: 01222 825111 Fax: 01222 823036/825466	The Secretary South Wales Regional Working Party on Aggregates Bridgend CBC PO Box 4 Civic Offices Angel Street Bridgend CF31 1LX Tel: 01656 643643 Fax: 01656 643190
Welsh Development Agency QED Centre Main Avenue Treforest Estate Pontypridd CF37 5YR Tel: 01443 845506 Fax: 01443 845588	

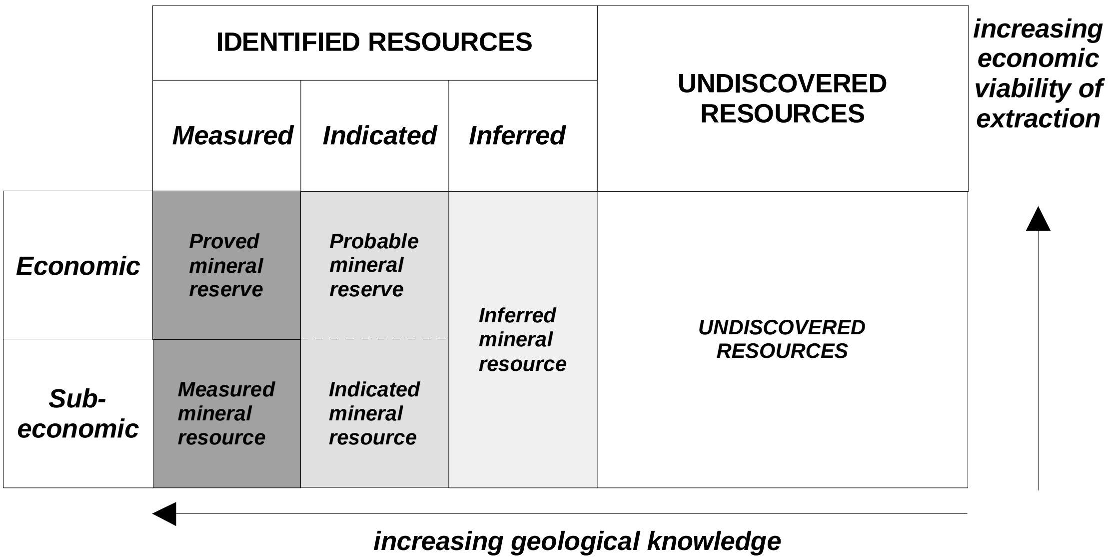
APPENDIX 3 Methodology

The British Geological Survey (BGS) was commissioned in 1993 by the Department of the Environment to prepare, on a trial basis, a set of concise statements mainly in map form, to show the broad distribution of mineral resources in selected counties and to relate these to selected, nationally-designated planning constraints. The trial study developed a methodology for the collection and display of data in a consistent and comparable format for four Mineral Planning Authority (MPA) areas - Bedfordshire, Derbyshire, Staffordshire and the Peak District National Park. The concept developed by the BGS for the trial study is now being extended to some twenty mineral planning authorities in England and Wales through a further phase of the project which started in 1996.

The main element of the trial study was the production of maps, with accompanying interpretative reports, for each MPA area. All mineral resource and planning constraint information has been collated digitally on a PC-based system using Intergraph Microstation to produce a cartographic database. Data has been captured as a series of files, structured on separate levels so that they can be viewed either independently or in various combinations, as required. Most of the information has been taken digitally from hard copy maps, mainly with scales between 1:50 000 and 1:10 000. Other material was obtained in a variety of digital formats which have had to be converted for use by the Intergraph Microstation System. The structure of the information will allow the data to be transferred in digital form to the BGS MINGOL (MINerals GIS On-Line) system. MINGOL is being developed to provide a decision-support system for the rapid solution of minerals-related problems to aid corporate and public resource management. It applies a state-of-the art GIS to relate the nature and distribution of mineral resources to other information such as planning and environmental constraints, and mineral exploration, borehole and commodity statistics datasets.

As the data are held digitally, map output can be on any scale but 1:100 000 has been found to be a convenient size to summarise the information for individual MPAs. This provides a legible topographic base which enables both the broad implications of the information, and sufficiently accurate detail, to be shown. The particular advantage of holding all the information in digital form is that it is comparatively easy to update and revise as additional information becomes available, and also provides scope for producing customised maps of selected information or areas on request.

Figure 1 Classification of resources



Based on McKelvey, 1972

Classification of reserves and resources

The diagram, Figure 1, is a representation of a conventional method for classifying mineral reserves and resources, based on a system introduced the US Bureau of Mines and the US Geological Survey and adapted by the British Geological Survey. In this conceptual diagram the vertical dimension of the diagram represents the economic viability of the resource and consists simply of two categories, **economic** and **sub-economic**, depending on whether or not it is commercially viable under prevailing economic circumstances. As demand, mineral prices and costs of extraction may change with time, so mineral resources may become reserves and vice versa.

The horizontal dimension represents degrees of geological knowledge about the resource, from mere speculation about its existence (right-hand side) to thorough assessment and sampling on a systematic basis (left-hand side).

In the present study the mineral resource information has been produced by the collation and interpretation of data principally held by the British Geological Survey. Since the mineral resource data presented are not comprehensive and the quality is variable, the boundaries shown are approximate. Most of the mineral resource information presented is, therefore, in the **inferred resource** category (Figure 1), that is to say, those resources that can be defined from available geological information and which may have some economic potential. They have neither been evaluated by drilling, or other sampling methods, nor had their technical properties characterised on any systematic basis. Inferred resources may be converted into indicated and measured resources with increasing degrees of investigation and assessment.

A mineral resource is not confirmed as economic until it is proved by a relatively expensive evaluation programme. This usually involves a detailed measurement of the material available for extraction together with an evaluation of the quality of the material, its market suitability, the revenues generated by its sale and, ultimately, the viability of the deposit. This activity is an essential precursor to submitting a planning application for mineral extraction. That part of a resource that is both 'measured' and 'economic', i.e. that has been fully evaluated and is commercially viable to work, is called a **reserve** or **mineral reserve**. It is customary to distinguish **proved** and **probable reserves**, which correspond to the economic parts of measured and indicated resources respectively (Figure 1).

In the context of land-use planning, however, the term **reserve** should strictly be further limited to those minerals for which a valid planning permission for extraction exists, i.e. **permitted reserves**. The extent of mineral planning permissions (other than coal) is shown on the Mineral Resources Map. These cover both active mineral workings and inactive mineral workings. Some mineral planning permissions may have remained unworked, and others may have become uneconomic prior to being worked out. In many cases the areas involved are likely to have been worked to some extent in the past, and may now be restored. In addition, parts of the resource areas may have been fully evaluated by the minerals industry, but either have not been subject to a planning application or have been refused permission for extraction. These areas are not depicted on the map.

A **landbank** is a stock of planning permissions and is commonly quoted for aggregates. It is composed of the sum of all **permitted reserves** at active and inactive sites at a given point of time, and for a given area, with the following provisos:

- it includes the estimated quantity of reserves with valid planning permission at dormant or currently non-working sites;
- it includes all reserves with valid planning permission irrespective of the size of the reserves and production capacity of particular sites;
- it does not include estimated quantities of material allocated in development plans but not having the benefit of planning permission; and
- it does not include any estimate for the contribution that could be made by marine dredged, imported or secondary materials.

It is important to recognise, however, that some of the permitted reserves contained within landbanks have not been fully evaluated with the degree of precision normally associated with the strict use of the term reserves, indeed some may not have been evaluated at all.

Mineral workings and planning permissions

The locations and names of mineral workings are shown on the maps. The information is derived from the British Geological Survey's Mines and Quarries Database, updated as appropriate from the Coal Authority's and Mineral Planning Authorities' records. Letters (e.g. **Lst** = limestone) are used to show the main mineral commodity produced.

The extent of the planning permissions shown on the Mineral Resources Map cover active mineral workings, former mineral workings and, occasionally, unworked deposits. The present physical and legal status of the planning permissions is not qualified on the map. The areas shown may, therefore, included inactive sites, where the permission has expired due to the terms of the permission, i.e. a time limit, and inactive (dormant) sites where the permission still exists. Sites which have been restored are not separately identified. Under the provisions of the Environment Act 1995, after 1st November 1995 sites that are classed as 'dormant' may no longer be worked until full modern planning conditions have been approved by the Mineral Planning Authority. A 'dormant' site is defined as a site where no mineral development has taken place to any substantial extent in the period beginning 22nd February 1982 and ending 6th June 1995. Information on the precise status and extent of individual planning permissions should be sought from the appropriate MPA.

Most planning permissions appear on a mapped mineral resource area and thus the underlying resource colour identifies the mineral type. This is not the case in the following circumstances:

- where a planning permission for one mineral overlies another resource area

- where no resource has been mapped

Planning permissions may fall outside resource areas for the following reasons:

- some old permissions may be for minerals which are no longer of major economic importance and no resource has, therefore, been mapped
- permissions shown partly off resource areas may extend to ownership, or other easily defined boundaries, or to include ground for ancillary facilities such as processing plants, roads and overburden tipping

Isolated workings occurring outside defined resource areas may reflect very local or specific situations not applicable to the full extent of the underlying rock type.

APPENDIX 4 Summary of data on which the opencast coal resource areas are defined within BGS 1:50 000 geological sheets.

Sheet 229 - CARMARTHEN
The base of Zone 1 is placed at the outcrop of the Pumpquart Seam. Its top is placed at the outcrop of the Soap or Graigog Seam. The base of the lower Zone 2 is placed at the outcrop of the Rhasfach Seam, the top at the Pumpquart Seam. The base of the upper Zone 2 is placed at the outcrop of the Soap/Graigog Seam, the top at the outcrop of the Upper Brondini/Cenrhos Seam.

The geology of the area south of the Trimsaran Disturbance is complex and not known in detail. The zone boundaries in this area are therefore conjectural.

Sheet 230 - AMMANFORD
The base of Zone 1 is placed at the Pumpquart Seam. The top is placed at various levels, but generally at the topmost mapped coal in a group comprising the Stwrin, Penny Pieces and Soap. The Soap, the correlative of the Two Feet Nine, is thin and not mapped throughout, but present in the east and west. In the centre of the area, none of this group is mapped, presumably being thin, and the top is placed variously at the Green, Big and Rock seams. The base of the lower Zone is placed at the Rhasfach (Bryn or Cnapiog) Seam. The top is placed at the Pumpquart Seam.

The base of the middle Zone 2 is the top of Group 1 as defined above. The top is in general placed at the topmost coal beneath thick sandstone cover or at the base of the sandstone cover. In the west this is the Upper Llwydcoed Seam. In the centre of the area it is the Duke Seam, to the east the No. 1 Rhondda Rider, in the extreme east the No 2 Rhondda.

The upper Zone 2 includes areas of exploitable coal in the higher parts of the Upper Coal Measures, mainly of the Gelli Group coals and the Swansea seams.

Sheet 231 - MERTHYR TYDFIL
Zone 1 base lies at the Gellideg in the east, the Five Feet in the central area and the Rhyd in the west. Its top is placed at the Two Feet Nine in the east and the Stwrin in the west. The base of the lowest Zone 1 area is placed at the Garw (named the Cnapiog in the west). Its top is the base of Zone 1. The higher Zone 1 area is placed between the top of Zone 1 and the No 2 Rhondda. The latter is named the Ynysarwed in the west. Locally, Pennant sandstone facies extends below this to the Cambriense Marine Band. Locally also, the absence of thick sandstones above the No 2 Rhondda extends the zone up to the No 1 Rhondda. Smaller areas of Zone 2 resources occur at higher levels on the outcrops of the No 1 Rhondda and No 1 Rhondda Rider. Other smaller areas of coals in the Rhondda Beds and Brithdir Beds (not shown) may be exploitable.

Sheet 232 - ABERGAVENNY
The lower Zone 2 base lies at the Garw, its top at the Five Feet-Gellideg. Zone 1 extends from the Five Feet-Gellideg up to the Two Feet Nine in the west of the sheet area. However, the latter is a thin coal throughout most of the district, with the Upper Four Feet being the topmost thick coal of Zone 1. The middle Zone 2 extends from that coal up to the Brithdir. Higher Zone 2 resources are in areas of Mynyddislwyn, Big Rider and Small Rider coals, some of which have been extensively opencasted previously.

Sheet 246 - WORMS HEAD
There is no recent mapping of this sheet. A small area of coal in the Llanelli Syncline is shown as a Zone 2 resource.

Sheet 247 - SWANSEA
In the west, the base of Zone 1 is placed at the New Lynch, the top at the Fiery (or Frog Lane). In the east, the base is placed at the Gellideg, the top at the Two Feet Nine. In the west, the lowest Zone 2 area lies between the Lynch at the base and New Lynch at the top. The former coal lies below the Listeri Marine Band, the area is structurally complex and poorly known. The base of the middle Zone 2 lies at the Fiery/Frog Lane in the west and the Two Feet Nine in the east. The top is placed at the base of the Pennant sandstones, which lies close above the Cambriense Marine Band. Higher Zone 2 areas are in the argillaceous, coal-bearing outcrops of the Hughes, Swansea and Grovesend beds.

Sheet 248 - PONTYPRIDD

Zone 1 extends from the Gellideg at the base to the Two Feet Nine at the top. The lower Zone 2 extends from the Gellideg down to the Garw (Cnapiog). The higher Zone 2 extends up from the Two Feet Nine to the No 2 Rhondda (in the east) and Tormynydd (in the west). Zone 2 areas within the outcrop of the Upper Coal Measures include areas of Llantwit coals in the south-east and Betws Four Feet in the west, and of the Rhondda Beds in the Rhondda and Cynon valleys in the north-east.

Sheet 249 - NEWPORT

Zone 1 lies between the Five Feet - Gellideg and Two Feet Nine. The lower Zone 2 is too narrow to show over much of its outcrop, but where shown lies between the Garw and Five Feet-Gellideg. The middle Zone 2 extends from the Two Feet Nine up to the No 2 Rhondda in all but a small area north of the Glyn Fault in the extreme north, where the upper limit is placed at the Brithdir. Higher Zone 2 areas are outliers of the Llantwit (Mynyddislwyn) coals.

Sheet 262 - BRIDGEND

Strata dip steeply and the Garw to Gellideg outcrop is too narrow to show. The base of Zone 1 is therefore placed at the Garw. The top of Zone 1 is placed at the Two Feet Nine. Zone 2 resources lie above this coal. Some of the resources are concealed below Triassic cover, and all are affected by high-angle strike thrusting and faulting.